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D7.1 Report with summary of WP outputs over first 18 months and a roadmap of competence development programmes RTD

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Building the European Network
For Lifelong Competence Development

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Project Deliverable report

D7.1 - Report with summary of WP outputs over first 18 months and a roadmap of competence development programmes RTD

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Table of Contents

1 Introduction

In this deliverable we report on the outcomes of TENCompetence WP7, "Competence Development Programmes", as established during the first 18 months of the project.

In our largely knowledge-based society there is a growing need for continuing professional development, in order to deal with the evolving character of professional knowledge and technologies. Currently, education at high schools and universities is considered just the mere beginning of a process of *lifelong learning* (Cheetam and Chivers, 2005). Those learning activities that are aimed at maintaining or increasing the level of a worker's *competence* are generally called *competence development programmes.*

Competence development is generally not limited to formal learning activities that lead to certificates or degrees; many lifelong learning activities can be characterized as *non-formal learning* – on-the-spot training, possibly offered by peers –, or as *informal learning* – the acquisition of knowledge and skills by practice rather than intentional learning (European Commission, 2001).

In order to support these activities, a technological infrastructure is required for storing, organizing and sharing the various bodies of knowledge; in addition, this infrastructure should provide lifelong learners with learning objects that fit their individual background knowledge, learning objectives, and other needs.

Technological support for learning activities is not a new concept; a substantial amount of research has been carried out in the field of *adaptive and intelligent Web-based educational systems* (Brusilovsky and Peylo, 2003). However, the broader field of competence development poses several additional challenges and requirements, as compared to mere educational programmes.

In this introductory chapter we provide a general overview of the underlying concepts dealt with in work package 7. In the next section we summarize the work package objectives. In section 1.2 we sketch a more integrated view on the field of competence development programmes, which guides our research activities. Making use of this integrated view, in section 1.3 we present the outline of this deliverable, relating the subsequent chapters to the WP7 tasks and the different parts of our CDP model.

1.1 Work Package Objectives

Competence Development Programmes are formal or informal collections of learning activities and units of learning that are used to build competences in a certain discipline or job. Collections of learning activities and units of learning can be related and combined in various ways to form a programme (as contrasted to a unit of learning which is a tight integration of learning activities). Depending on the competences to be built, these programmes can be small (e.g. a crash course) or quite extensive (e.g. a masters programme). In addition to formal programmes offered by institutions, it is also possible to create individualized competence development programmes, based on individual user needs or exploratory behavior, and to exchange these individual programmes.

This work package is directed at the development of models and services to realize the creation, storage, search, retrieval and quality rating of competence development programmes. There are currently no standards available to describe programmes in an interoperable way. One of the objectives of the work package is to develop and evaluate concepts, methodologies and user interface designs that extend existing standards and to disseminate the results in order to create awareness and appreciation of the concepts.

The work in WP7 during the first 18 months is split into several independent yet interrelated tasks, which are listed below.

Task 1. Develop a learning path description specification that can be used to describe competence development programmes in a formal, semantic, computer interpretable, and interoperable way. Work during the first 18 months will cover this objective. The proposal will be formulated in line with existing standards where applicable, and will be brought to relevant standardisation bodies, among others CEN/ISSS and IMS.

Task 2. Develop and test a methodology for the effective & efficient development of competence development programmes using the learning path description specification. Work during the first 18 months will concentrate on 3-6 professions (e.g. teaching, character animation) or fields of expertise (e.g. social work, health care, digital film), and existing competence descriptions will be translated into standards based descriptions.

Task 3. Select and adapt existing tools, or develop prototypical tools for the creation, storage, search, retrieval, reuse, sharing and quality rating of competence development programmes to create the components in the second architectural layer that can be integrated as services at the third layer within the Integrated TENCompetence System. Work during the first 18 months will concentrate on the development of competence development programmes for the professions and fields selected under the previous objective.

Task 4. Develop and test a user positioning service for competence development programmes, using semantic web language technologies, data mining and latent semantic analysis, to create a cost-effective summative and formative assessment method for prior and posterior (target) competencies. Work during the first 18 months will concentrate on the development of prototypical components for an elementary positioning service. The service will be tested against the competence development programmes developed under the previous objective. The prototype must conform to the technical standards & architectural constraints as defined in the project under WP3, to ensure that it can be integrated in the second project cycle into the Integrated TENCompetence system.

Task 5. Develop and test a user navigation service for competence development programmes, based on collaborative filtering, planning and data mining techniques. Work during the first 18 months will concentrate on the development of prototypical tooling for an elementary navigation service, based a.o. on agent support and agent policies. The service will be tested against the competence development programmes developed under the previous objectives. The prototype must conform to the technical standards & architectural constraints as defined in the project under WP3, to ensure that it can be integrated in the second project cycle into the Integrated TENCompetence system.

Task 6. Develop and test a learner support service for competence development programmes. Work during the first 18 months will concentrate on the development of prototypical tooling for an elementary learner support service. Social network analysis, support and exploitation will underlay the development efforts. The service will be tested against the competence development programmes developed under the previous objectives. The prototype must conform to the technical standards & architectural constraints as defined in the project under WP3, to ensure that it can be integrated in the second project cycle into the Integrated TENCompetence system.

Task 7. Experiment with, and evaluate the usability of the components for competence programmes. Work during the first 18 months will concentrate on developing efficient and effective assessments that may be used to assess prior and posterior competencies for the competence development programmes developed under the previous objectives.

Task 8. Research and develop models and methods to stimulate and organise the creation, storage, search, retrieval, use, reuse, pro-active sharing and quality rating of competence development programmes. Identify gaps in our knowledge in this field and develop and contribute to the knowledge in the field (e.g. through academic publications). Work during the first 18 months will concentrate on consolidating these gaps into a roadmap for further research and development in the field. The roadmap will be used as input to planning activities for cycle 2 (month 13-30).

1.2 A More Integrated View on the Domain

In order to better appreciate the tasks and their interrelations, we have analyzed the domain of competence development programmes in more detail and separated concerns. This allows us to identify the boundaries between tasks and the input expected from other tasks and work packages.

In milestone M7.1 we presented a study on current initiatives to specify curricula, with subsequently a set of initial models for the various concerns: the competence development programme, the underlying domain and associated competences, the learner, the group of learners, and the adaptation logic, which is responsible for creating learner-centred competence development programmes. This section summarizes the results and shows how they relate to the work carried out in this work package.

Learners differ from each other, they have particular learning goals and different of levels of knowledge about the subject. At the same time, each programme has different entry requirements and targets various competences. Moreover, following only one programme (or part of a programme) will not be sufficient to acquire the required competences. Probably a combination and selection of different options will be needed. The challenge is to match the preferences, learning goals and competences of the learner with the (part of) programme or programmes available in order to recommend her or him with the most suitable learning path.

This implies to consider factors such as: (a) the learner characteristics, (b) the available curricula and (c) the topics and competences it fulfils, (d) the experiences and opinions other learners have had while they were learning form the same curricula, and the use of (e) an adaptation model that permits–either to a person or a software agent–to combine these factors and build different learning paths.

Following the area of adaptive hypermedia (Brusilovsky, 2003), and particularly (Paramythis & Loidl-Reisinger 2004), we propose to use a five-model approach that comprises: (a) a learner model, (b) a competence development programme model, (c) a domain model, (d) a group model and (e) an adaptive model. Figure 1 shows how these models interact between each other and their place within the TENCompetence domain model (Koper, 2006).

These models interact as follows:

1. The *learner model* contains information about the learner, such as preferences, characteristics, competences, finished units of learning, performed learning actions, and so on.
2. The competence development programme model (CDP model) contains collections of units of learning and actions that have to be studied in order to acquire certain proficiency level in a topic or meet the requirements of a function or job. In order to guarantee the comparability and exchangeability among the different available programmes, this model uses a uniform description, the learning path specification.
3. The domain model contains the required competences to acquire certain proficiency level in a topic to meet the requirements of a function or job. It is a competence map that helps to derive what competences the learner has and what competences the available CDPs fulfil. Following (Brusilovsky and Peylo, 2003), elements from the real-world domain can be mapped on the CDP model. Several kinds of mappings and indexing mechanisms can be thought of.
4. The group model: analogous to learner models, group models represent characteristics of a group of learners; these models are typically assembled dynamically; group identification may be done manually (e.g. stereotyping) or automatically (e.g. clustering). Group models play an important role in collaborative filtering and recommender systems, which bear great promise in the context of e-learning. Also, group models are used for ensuring sufficient cohesion between members of a group of learners.
5. The adaptation model generates the potential competence development programmes that a learner could follow in order to get his/her goal. In this model, two tasks, one after the other, are performed. The first one is a positioning task, which takes into account the learner model and the domain model to determine what the learner has done and what s/he has to do to achieve his/her goal. The second is a navigation task, which matches the potential CDPs and the learner preferences to recommend the most suitable ones. In Figure 1 these tasks are pointed out, respectively, as 1 and 2. More generally, from the field of adaptive hypermedia several inference techniques and adaptation mechanisms are known and used in e-learning environments.

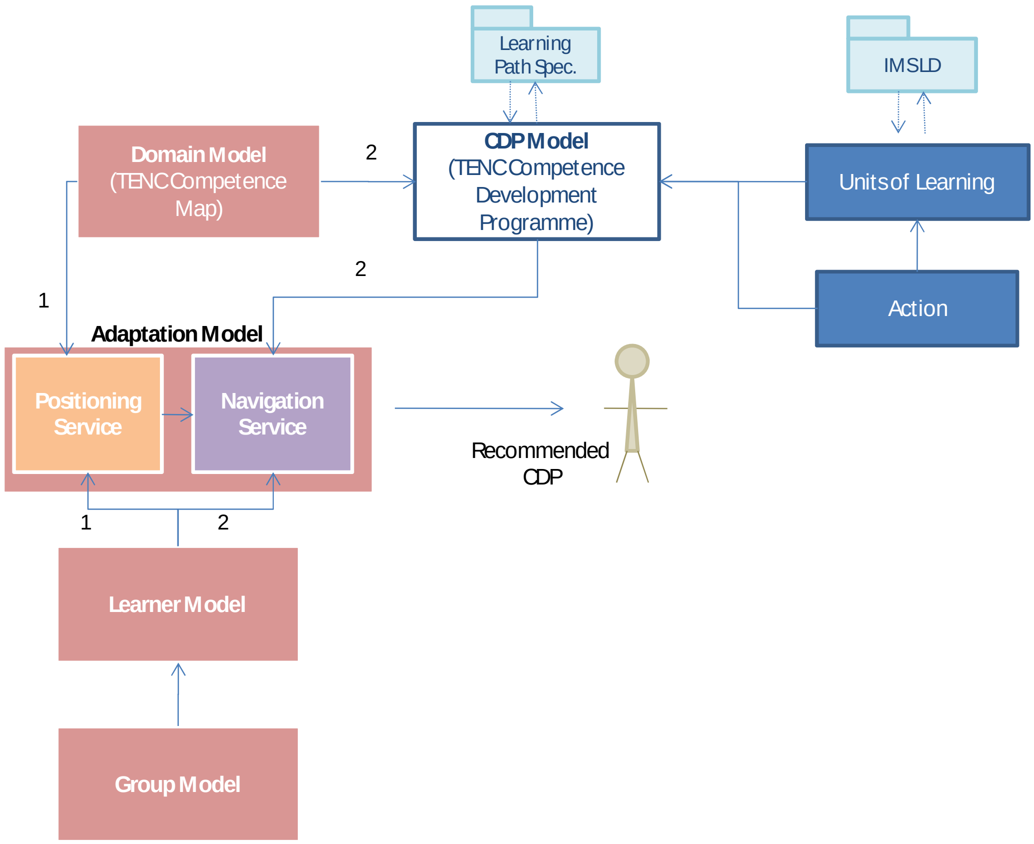


Figure 1. The proposed model and TENCompetence

1.3 Work Done in the First Cycle and Document Overview

As can be observed from figure 1, the *learning path description* of the CDPModel does not stand on itself. The description of the *CDP Model* should allow the A*daptation Model* to provide the envisaged positioning and navigation services. For the adaptation, additional information on the *learner* and the underlying *domain* and associated competences is needed.

In the first eighteen months of the project, we have gradually zoomed in on the CDP model and the Adaptation Model, making sure that our efforts fit in the bigger picture and that external factors are taken into account.

Learning Path Description (task 1)
On the one hand, we concentrated on the learning path description itself. By combining insights from current initiatives for describing curricula, theoretical work on adaptive hypermedia and an evaluation of the suitability of IMS Learning Design to model the domain of the Psychology Curriculum of the Open University of the Netherlands, we have defined the boundaries of what the learning path description should comprise, and which information should be present in the model itself. In chapter 2 we present our initial model of the Learning Path Description, which heavily builds upon the existing IMS Learning Design (IMS LD) Specification. In addition to the theoretical motivations, a further argument for reusing IMS LD is the widespread acceptance and

uptake of this specification. This will pedigree the uptake of the Learning Path Specification, as will be further developed within this work package.

Methodology for CDP development (task 2)
A specification provides no benefit by its mere existence. Authors need tools for developing curricula that adhere to the specification, aided by tools that provide integrative overviews, editing functionality and intelligent feedback. In chapter 3 we provide background research on current practices for curriculum planning and information visualization. Existing tools are reviewed, as well as more general information visualization tools. Two scenarios are used for exemplifying the current issues. These scenarios include the domain of Digital Cinema, which will be used as a pilot within the TENCompetence Project.

Tools for the development of CDPs (task 3)
Based on the insights gained from the background research as reported in chapter 3, three prototypic tools are developed for the creation and deployment of competence development programmes. These tools are presented in chapter 4. The first prototype provides a high level user interface scenario for future CDP authoring tools. This prototype delivers guidelines on how to develop functioning prototypes. A less advanced yet fully functional prototype is presented in section 4.2. It provides various visual overviews of learning units on several levels of abstraction, query interfaces, a curriculum planning tool and a subsequent curriculum scheduling interface. We aim to integrate the concepts of the whiteboard prototype with the running prototype. As a third strategy, we extended an existing algorithmic curriculum planner. A Prolog-based reasoning mechanism is used for generating possible curricula that fulfill learner requirements. The algorithmic curriculum planner currently functions in the domain of the Computer Science curriculum at the University of Hannover. This tool will be used as a recommender system in the CDP authoring and planning prototype.

Adaptive technology: positioning and navigation support (task 4 and 5)
The practical insights from the prototypic CDP authoring tools feed the requirements and guidelines for the development of the learning path description. In a similar way, the applicability of the learning path description is evaluated by the adaptation models, which are developed in the context of tasks four and five. **Chapter 5** summarizes the results of research on the positioning and navigation services, which match various individual characteristics with the possibly vast variety of learning content.

Positioning Service (section 5.1)
Positioning is the process of mapping learner characteristics – as received by an e-portfolio or by a personal competence development plan – onto learning programmes which consist of learning units in a learning network. The position process should enable to select those learning units that are relevant to a learner's individual goal, and to leave out learning units that are not relevant, already known, or beyond a learner's current capabilities. Our initial approach is to explore the use of *latent semantic analysis* and similar *Reduced Rank Vector Models*. These are bottom-up-techniques from the field of information retrieval that reduce the need for extensive metadata.

Navigation Services: Recommendation and Preference-Based (section 5.2 and 5.3)
Once the learner has been positioned in a learning network, there is the need for an adaptive and flexible approach to provide the learners with means for orienting and navigating through a learning network's learning courses and units. *Navigation* is the process of finding / providing a learning route through selected learning activities.

Our initial approach entails the development of a best-next recommender that provides personalized advice on the best-next learning activity to study. The navigation service recommends most suitable learning activities to learners regarding their personal needs and preferences. For this purpose we aim to develop a personal recommender system (PRS) that will use combinations of various recommendation techniques (see section 5.2).

Whereas a recommendation service, based on the behavior of peer learners, is suitable for finding learning routes in classical learner contexts, this technique is likely not to be suitable for lifelong learners who need to find suitable learning activities that match their personal and professional situation. For situations in which few or no comparable peer learners are available, we developed a preference-based navigation service, which provides a Sky lining approach to select the material that matches the learners' individual context (see section 5.3).

Again, our strategy is to develop two independent prototypes, of which the most successful concepts will be integrated in cycle two of the TENCompetence project.

Learner Support Service (task 6)

A third service that was aimed to be developed within the context of WP7, is the *learner support service*. A learning network is, among other things, a community of people (members) who share the intention to learn something about a particular domain of knowledge. Through active participation in the community, the learning goals people have set for themselves will be attained more effectively, more efficiently, more attractively; or, put differently, reshaping a learning network as a community enhances the quality of the members' learning experience.

This *learner support service* was originally envisaged to be developed by WP7. As it turned out that learner support takes place on the level of learner networks rather than on the level of competence development programmes, this service is under development in WP8. They apply innovative educational technology and ICT to create and populate ad hoc transient communities in which peer tutors instead of institutional tutors provide support to tutees. A detailed treatise of the learner support service can be found in M8.1 (http://hdl.handle.net/1820/880), chapter 4 (page 195ff).

Learner Assessment (task 7)

Competence assessment is the assessment of what a learner has learned with respect to a specific competence. Competence assessment assesses the proficiency level of a specific competence as a whole, not only a part of that specific competence. In general, assessment involves the collection of evidence on performance or capability. Whereas competence assessment - in contrast with traditional assessment - is not directly tied to a specific course of training, there is quite some overlap with assessment on the level of units of learning. For this reason, the research carried out in the context of WP7 and, in particular in the context of WP6, has been reported in milestone 6.1. We refer to chapter C of the milestone for further details.

As can be seen in figure 1, competence assessment remains relevant for our work on the learning path description, authoring tools and adaptive learner support. Competence assessment is the process by which the learner model is coupled with the domain model, identifying the learner's competences within the domain. For this reason, we will make use of the results of WP6's assessment task force's effort as input for further development of the learning path description and the adaptation technology.

Roadmap (task 8)
In chapter 6 we draw conclusions on the work reported in the earlier chapter. We sketch a roadmap for further research and identify issues to be solved. A significant part of the research reported in this deliverable has been submitted to conferences and journals. This will further foster the knowledge in the field and contribute to our progress.

2 Learning Path Description

2.1 Introduction

What is a learning path description, and why would we need such a thing? These obvious questions came to our mind when reading the various specifications and standardization efforts that are out there in the field of e-learning. Certainly, a motivation for seeking standardization in e-learning is reduction of costs for initial investment and maintenance, transfer of learning material, inter-operation between various systems, content discovery and aggregation (Paramythis, 2004). On the other hand, standardization may impede progress in a field that may not be young in age, but that certainly has not reached maturity yet.

There seems to be a dichotomy between commercial, standards-compliant e-learning systems and *adaptive* learning environments, which typically do not follow any standards; this dichotomy is in part due to the lack of sufficient support for adaptive behavior in existing standards. It may not be obvious that adaptive behavior is needed or even desirable for e-learning, until one realizes that learning becomes more and more an individualized experience, targeted at learners with specific needs, who learn in a particular context with individual goals - most notably in the context of lifelong learning that goes beyond the traditional schools and other educational institutes. As e-learning only becomes cost-efficient once a minimum critical mass is reached, electronic educational is typically targeted at a larger scale.

In chapter 2 of milestone M7.1 we provided an overview of several European initiatives toward course metadata, among which the European Credit Transfer and Accumulation System (ECTS), Course Description Metadata (CDM) and eXchanging Course-Related Information (XCRI). Besides differences in focus, we found that close analysis is needed for selecting a minimum set of metadata needed for a learning path specification. Further, we saw the need for additional modeling of the underlying competences that are offered by these programmes, in order to match the needs of lifelong learners. We further identified the need for learner modeling and personalization techniques.

In this chapter, we focus on the core of the learning path specification, the CDP model. In the next section, we shortly recapitulate on the models that we distinguished in the milestone M7.1, and that were briefly touched upon in section 1.2 of this deliverable.

2.2 Breakdown in Several Models for Lifelong Learning

In this section we briefly repeat the main findings of the modeling efforts reported in milestone M7.1. We found that a separation of concerns is highly important for reasoning within learner-adaptive environments. It should be noted that the models, though presented separately, are in fact closely connected – they are the constituent parts of one large model.

2.2.1 The CDP Model

The CDP model as presented in section 4.1 of M7.1 is the core of the learning path description. We identified several objects and relations that should be present. As the CDP model has been considerably reworked, and as it will be presented in section 2.3, no further details are presented in this subsection.

As mentioned earlier, the CDP model provides a means to describe formal, non-formal and informal curricula. The model has several relations with the models that will be presented in the remaining part of this section. As an example, in order to reason on the underlying competences, the CDP model should provide links to the corresponding competence model. Similarly, the learner model should be matched with attributes within the CDP model. Research on these other models will remain necessary to feed into the final CDP model and the learning path description.

2.2.2 The Domain Model

In addition to the CDP model, learners need to be able to search for e-learning content in a goal-driven manner - based on the competences that they want to acquire for their work, or private life (`I want to be able to speak some basic Chinese during my long holidays'). This calls for a domain model that represents the relevant activities and associated competences rather than the available Units of Learning.

As a basis for the domain model, we took the TENCompetence model (Koper, 2006) with some slight changes to better represent our needs. In short, the model describes competences in terms of a competency, a context and a proficiency level. In order to cater more complex situations, such as competences that are composed of other competences – for which there may be several alternatives – we provided means for aggregation and selection of alternatives. A more detailed reporting of our approach can be found in (De Coi et al., 2007).

2.2.3 The Learner and Group Model

Like regular user models, a learner model may consist of explicitly given or inferred *user data* and a log of the learner's interaction with the system, the *usage data*. Parts of the model may be rather static, such as demographic data and long-term interests; other parts may be dynamic, such as a list of current learning activities.

A minimum number of relation types between learners and units of learning found in the literature are: `interest level', `knowledge level', `status' (e.g. not followed, selected, planned, being carried out, finished) and the grade obtained (if any).

In addition to the overlay model, learners may have a learning history (list of followed courses, certificates, examples of own work), which are stored in an ePortfolio. What such an ePortfolio looks like - or should look like - is far from clear - see (IMS ePortfolio). For this reason we chose, again, for a freeform representation of profile elements. An important role of the profile elements is that they can function as an *assertion* that a learner has a certain competence.

For class- or group-based education, the use of individualized generation of learning material requires coordination of the planning mechanism on the group level. Existing standards do not support the description of characteristics that are shared between group participants. As a result, it can only be indirectly modeled what semantic information would qualify a person as a member of a group (Paramythis et al., 2004). From the field of user modeling, three approaches can be distinguished: stereotyping, clustering and the use of overlay models.

2.2.4 The Adaptation Model

What we call the ’adaptation model' is in principle a set of rules that are used for providing the learner with (personalized) access to the learning resources. These rules make use of the attributes and relations described in the previous subsections. What these rules exactly look like, depends on the application context and the reasoning mechanisms used. Various possible approaches to reasoning on the learner model and adaptive elearning technologies are described in section 3.2 of Milestone M7.1

2.3 CDP Model

In this section we present the second iteration of the Competence Development Programme Model. The model stems from the results reported in milestone M7.1, together with a requirement analysis for the learning path specification, as reported in Appendix 2 (Janssen et al, submitted).

As we already mentioned, Competence Development Programmes (CDP) are formal or informal collections of units of learning and/or actions that have to be studied in order to acquire certain proficiency level or to meet the requirements of a function or job. The level of granularity of these programmes depends on the competencies to be built. They can be, for example, a master´s in Psychology or a one-day course to install a server. Their structure is built upon conditions that, for instance, define whether or not an element is compulsory, if there are a number of units to select or if a specific order should be followed.

In the context of lifelong learning, and particularly for the TENCompetence project (Koper & Specht, 2006), a CDP Model should allow personalization of learning paths, combination of formal and informal learning offers, description of conditional rules (to define restrictions, sequences, selections, requirements, and so on), interoperability of formal and informal learning paths among different users and systems, and automatic processing of these paths by software agents.

Given the pedigree of IMS Learning Design (IMS LD, 2003) as an educational modelling language we —as Tattersall, Janssen, Van den Berg, & Koper (2006) did— tested its suitability to model CDPs and, at the same time, explored the description of a real CDP.

IMS-LD allows specifying which roles should carry out which activities, using which supportive materials and services, in order to achieve certain learning objectives. In IMS-LD a Unit of Learning describes an activity structure that can refer to either activities (learning and/or support activities) or other units of learning, thus allowing for both modular and nested compositions. Moreover activity structures can be defined as selections or sequences. A selection indicates that the units in the structure can be done in any order. Besides in a selection it is possible to specify the number of units to select, indicating that it suffices for a learner to choose and complete for instance three units (modules) out of the entire range of units presented, in order to fulfill the requirements of a free choice block within the curriculum. Defining an activity structure as a sequence on the other hand indicates that the units presented all have to be completed in the given order. Combined selections and sequences are basic constructs to model choice and obligatory units and their order within a programme. Moreover, IMS-LD has an expression language that can be used to define complex rules for completion (e.g. “if either document x has been approved of by the tutor or the learner has passed test y than the activity can be set to completed”) or to specify other conditions (e.g. “if learner x has background y than show supportive material z”). Finally, IMS-LD is an open specification using the XML Schema formalism so it allows exchanging information among different systems as well as automatic processing.

To test its suitability we chose the OUNL Psychology curriculum. Technical speaking, the use of IMS-LD in this exercise – as reported in section 5.1 of milestone M7.1 – showed that this specification is flexible enough to permit the description of CDPs. Nesting different learning activity structures using the selection and sequencing attributes was sufficient to model the Bachelors and Master Psychology programmes. Moreover, it was possible to reuse activity structures and courses among different phases and sub-phases of these programmes.

From this test we can safely assume that IMS-LD is appropriate to model curricula. However, to be able to compare and exchange formal and informal programmes among different provides a learning path specification is needed. Relevant characteristics of the programme, as its cost, schedule or delivery mode, have to be taken into account to recommend a programme to a particular learner.

Appendix 2 (Janssen et al., submitted) comprehensively describes the requirements for a learning path specification. It begins explaining the functional needs of a learning path specification in the context of Learning Networks. Thereafter, it explores the requirements for this specification form two perspectives: a review of the literature on curriculum design, and an analysis of a number of initiatives aiming towards exchangeability. In the first case, the goal was to investigate the structure and rules connected to a learning path and, in the second, to identify what characteristics these initiatives provide or propose to facilitate learners' decision-making. From the review of the literature on curriculum design, the following requirements for a learning path specification have been drawn:

- *Modular composition*: learning paths must be able to be built from units.
- *Nested composition: learning paths must be able to be composed of other learning paths.*
- *Learning outcomes: learning paths are defined in terms of learning outcomes.*
- *Entry requirements: it must be possible to specify entry requirements for a learning path.*
- *Selection: it must be possible to specify which elements of a learning path are mandatory and which are optional.*
- *Sequencing: it must be possible to specify a fixed order in which elements of a curriculum are to be completed.*
- *Temporal coordination: a learning path specification must enable to express parallel programming of two or more learning actions.*
- *Completion: the requirements for completion of a learning path must be able to be specified*
- *Conditional composition: it must be possible to specify conditions under which learning path elements are to be included or excluded.*
- *Substitution: learning path specification must enable description of substitution rules. Substitution rules describe which units in the learning path might be replaced and the criteria that exist regarding the substitute.*
- *Formality: the language must describe a route in a formal way, so that automatic processing is possible.*
- *Interoperability: the language must support interoperability of routes so that different support systems can share and exchange inf*ormation.

IMS-LD looks as the ideal candidate to realize these requirements. describes how each one of them can be met using the IMS-LD specification. Table 1 describes how each one of them can be met using the IMS-LD specification.

Table 1: Usability of IMS-LD as learning path specification

Requirement	IMS-LD
1. Modular composition 2. Nested composition	A Unit of Learning (UoL - read: learning path) describes an Activity Structure (AS) that refers to either activities (learning actions) or other UoLs (=LPs)
3. Learning outcomes	In IMS-LD it is possible to specify learning objectives on the level of both an activity and a UoL.
4. Entry requirements	In IMS-LD it is possible to specify prerequisites on the level of both an activity and a UoL.
5. Selection 6. Sequencing	An Activity Structure is defined as either a selection or a sequence. A selection indicates that the referenced items can be done in any order and through specification of a number to select it is possible to define a free choice range. Sequences are used to define mandatory items and a fixed order.
7. Temporal coordination	The Method part of LD defines the workflow (Play) through Acts. In an Act an Activity Structure it is linked to a role. By linking an Activity Structures containing one activity to the role of learner and another one also to the role of learner and furthermore specifying a time limit for the act, it is possible to define that two learning actions have to be done in parallel.
8. Completion	IMS-LD contains an expression language that can be used to define complex rules for completion (e.g. ‘if assignment X has been approved by the tutor’), next to more straightforward completion rules (user choice).
9. Conditional composition	The expression language mentioned under 8 can also be used to define conditional / adaptive compositions: “if learner has preference A, then show Activity B or Play C”
10. Substitution	The expression language mentioned under 8 can also be used to define substitution rules: “if UoL has property X, then show Activity Structure W”
11. Formality 12. Interoperability	IMS-LD is an open specification using the XML schema formalism.

Based on these requirements and on the analysis of the initiatives aiming exchangeability of learning actions, such as portals, general guidelines and application profiles (see Annex 2 for details), a first version of a learning path specification model is proposed. The model, which is shown in Figure 2, maps the Learning Networks and learning path terminology on IMS-LD elements (between brackets) and includes the minimal set of metadata required for learners to decide upon a suitable learning path.

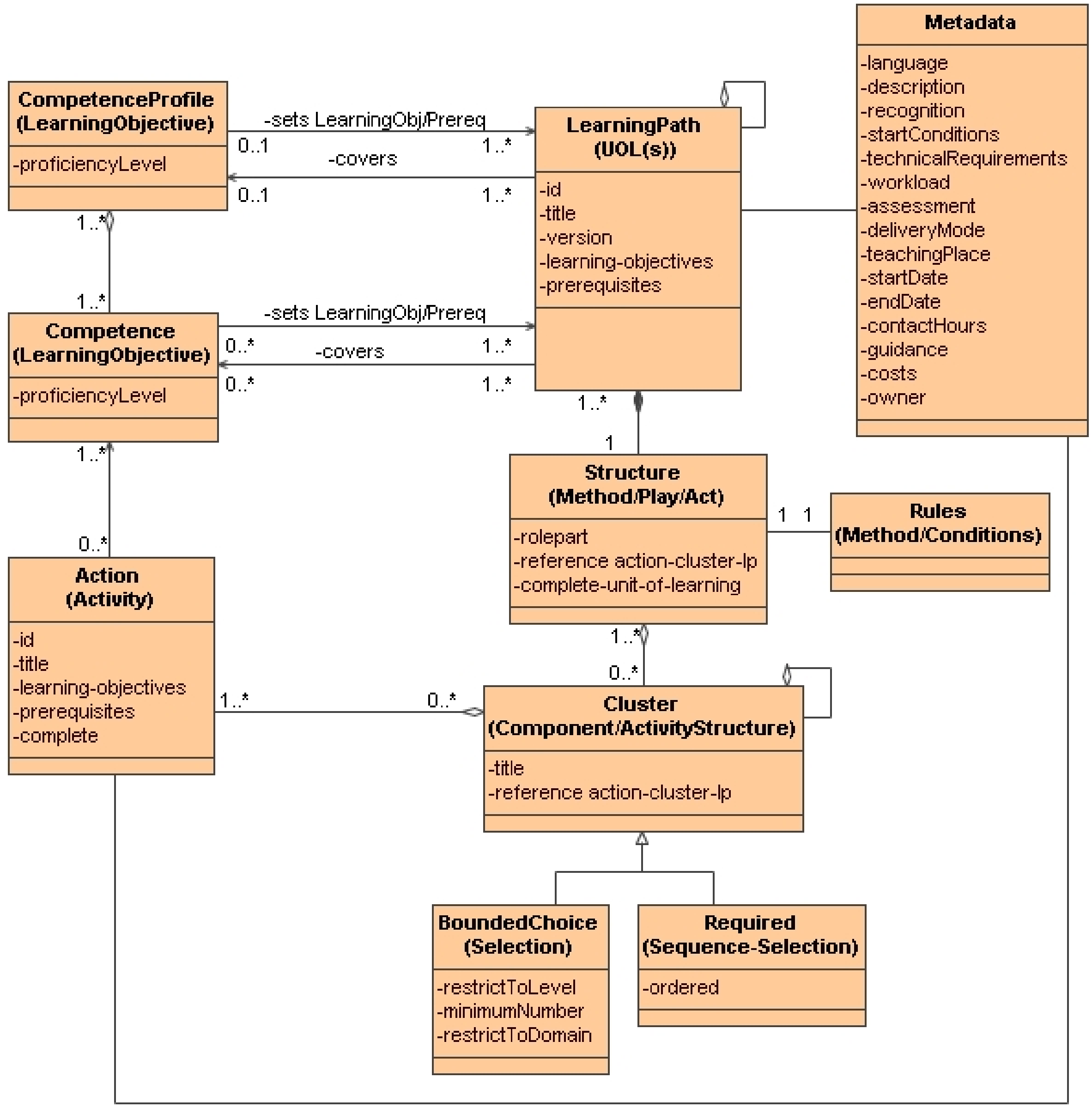


Figure 2. Learning Path model (Janssen *et al*, 2007)

A learning path leads to the acquirement of one or more competences and/or to a competence profile. It describes a structure of one or more actions, clusters of actions, or learning paths, that can be combined to represent a learning/work flow. These combinations contain the possible restrictions and degrees of freedom to develop competences along the path. Restrictions and degrees of freedom can be described through structuring principles (optional/required elements or rules) or through metadata (e.g. delivery mode, teaching place, contact hours etc.)
Table 2 provides a more detailed description of the classes of the learning path model and their attributes.

Table 2. Classes and attributes of the Learning Path model (Janssen *et al.*, 2007)

Class /attribute	Description
LearningPath	A Learning path describes the actions a learner has to perform in order to attain a competence or competence profile.
identifier	An identifier that can be used to refer to the learning.
title	Title of the learning path equals the title of the action when the learning path consists of a single action.
version	Versioning will be necessary to allow for updates of learning paths and enable identification of specific versions.
learning-objectives	Describe the intended outcome for learners.
prerequisites	Describes the entry-requirements for learners in terms of competences (knowledge, skills, and attitudes). It still remains to be seen whether and how the distinction between formal and recommended prerequisites must be made.
CompetenceProfile/ Competence	A competence profile describes the set of competences a person has to master in order to perform adequately in a particular job or function. Competence is defined as the ability of an actor to act effectively and efficiently in an ecological niche (e.g. occupation, hobby, sport etc).
Proficiency Level	Competence profiles and competences can have one or more proficiency levels, i.e. levels of mastery (novice, expert, etc.).
Action	Any activity performed with the aim to develop a competence. Actions have the same attributes as learning paths.
identifier, title etc	See: Learning Path
complete	Contains a choice of elements to specify when an activity is completed, e.g. when certain task has been completed, by user choice.
Structure	The structure defines the ‘work/learning flow’ of a learning path and its constituent parts.
Role part	The structure is defined by linking roles (learner, teacher, tutor, assessor) to actions, clusters of actions or learning paths by referring to them.
reference	
Complete-unit-of-learning	Specifies when a learning path can be considered completed, e.g. upon passing examination, by user choice, on a time-limit. Without this element completion is ‘unlimited’.
Rules	Rules can be used to specify whether some actions, clusters or learning paths should be included or excluded under certain conditions.
Cluster	A cluster is used to group actions (and/or clusters and/or learning paths) that are somehow related, for instance because they compose a set a learner can choose from, or because they have to be studied in a particular order. See below.
title	A header for the grouping of actions, clusters, and/or learning paths.
Bounded Choice	Bounded choice describes a cluster of actions, clusters and/or learning paths a learner can choose from.
Restrict To Level	Specifies that the cluster should only contain elements that relate to a certain level.
Minimum Number	Specifies the number of elements from the given set that the learner has to minimally complete.
Restrict To Domain	Specifies that the cluster should only contain elements that relate to a certain domain.
Required	A cluster of actions, clusters, and/or learning paths a learner has to complete either in a specific order (sequence) or in a free order (selection) to complete the learning path.
ordered	Specifies whether or not the elements of the cluster have to be completed in the given order.
Metadata	Characteristics of the learning path which are relevant to learner’s screening and eventual choice of a learning path.

language	Specifies which language(s) the learner needs to know to follow the learning path.
description	General description of the learning path.
recognition	This attribute only states whether completion of the learning path leads to a formal recognition (diploma/certificate). (N.B.: this is not the same as distinguishing between formal, non-formal, and informal learning. Formal learning not necessarily results in formal recognition).
start Conditions	Several entry or start requirements may hold apart from the required competences (prerequisites) e.g. a specific diploma or course certificate, a minimum age or minimum average grade. Other conditions might relate to practical or pedagogical issues: a minimum number of enrolments.
technical Requirements	Specifies technical equipment and tools a learner needs in order to take this path.
workload	The total workload in hours.
assessment	Describes which formative and/or summative assessments are in place to determine to what extend the learner has attained the competence.
delivery Mode	Describes the modes used for delivery of the learning path, e.g. distance learning using all kinds of media, face-to-face teaching etc. We expect this attribute to be important for initial selection (screening) of relevant learning paths to choose from.
teaching Place	In case a learning path requires face-to-face meetings the learner needs to know where they take place in order to decide whether this suits him/her.
start Date	In case there are fixed starting dates for a learning path, for instance in a semester schedule, this information is needed to see whether it fits the learner's needs and schedule. This attribute will be empty in case learners are free to start whenever they want.
end Date	See start Date.
contact Hours	Contact hours informs on the hours the learner is expected to attend (virtual) meetings. Teaching place, workload, start date and end date together still don't suffice to provide the learner with complete picture of the flexibility of the learning path in terms of time, place and pace.
guidance	Describes what support is available to learners taking the learning path (tutoring, counselling, helpdesk…).
costs	Specifies costs for enrolment and additional expenses (books, tools, etc.)
owner	Links to a webpage containing more detailed information on the owner of the learning path (person or institution), enrolment, accreditation regulations, facilities for special needs students, contact information etc.

The learning path model is the baseline of the CDP model. In this way the adaptation model (through the navigation service) can recommend the most suitable CDPs to the learner by searching in the Learning Network for those CDPs which attributes coincide with the competences the student wants to achieve, his/her preferences (stored in the learner model), and the successful learning paths followed by others (stored in the group model).

2.4 Conclusions

Our research towards a *learning path specification* will focus on the refinement of the current version. First, the documentation of the specification will be produced (i.e., UML model, information model and binding). In parallel, an exploration of the adequacy of IMS-LD to model the learning path specification will be conducted. This will provide feedback to reshape the documentation and insights of until what extent IMS-LD is sufficient or if any addition is needed.

Afterwards, an evaluation and validation will be conducted to check whether the specification enables the description of a selection of existing programmes. This will bring information to improve the current proposal. Thereafter, input to build a prototypical software to store and exchange learning paths will be provided, and through its integration with the TENCompetence pilot in 2008, the evidence of the appropriateness of the learning path specification to facilitate automated generation of navigational support will be evaluated.

3 Current Practices for Curriculum Planning

This section reports on the background research on requirements and current approaches to editors for curriculum designers. First we cover the current trends in the domains related to the visualization and human-information interaction. This theoretical knowledge may seem at first a bit unrelated to practical work performed within the work package. However, the concepts presented are important considerations that must be kept in mind while designing and building tools for CDP authoring. Following the first three theoretical sections, we define the requirements of curriculum editors. To do so, we describe, analyze and compare the current approaches in the field of curriculum designers with the examples of LAMS, Moodle, and RELOAD (to be found in Appendix 3.1). From this state of the art review, we highlight the main issues related to the design of a CDP composer and extract the good ideas, practices and approaches to create a new generation of editors.

3.1 Design challenges

Visual tools should be designed to be both displays and search tools at the same time (Schneiderman et al, 2000) Some visual schemes generate only one view per information space, but allow the user to zoom in and out, rotate, or in general change his/her own viewpoint on the image resultant from the visualization. This approach to visualizing information spaces inhibits searching and browsing by making it difficult for users to isolate, identify, and analyze parts or aspects of the information space. Users should be allowed to customize and control the manner that the tool at hands addresses information spaces. Moreover, users should be able to specify which part of the information space to visualize in a dynamic manner, making browsing and re-querying information spaces a process of moving between different views and viewpoints at the same time. The latter approach is not only based on the fact that tools should allow free browsing, but also on the general need of users to identify relations within the information space and between information spaces as well. This engenders the necessity to represent a number of information spaces simultaneously within the same visualization or within a number of independent windows with tiling or any other design choice that developers might commit to answer this need. On the other hand, designers should pay attention to what is being afforded as well as what is not being afforded in the global aspect of visualization. For example, interactive cues or cues that abstract subsets of information and could be expanded upon the user's request should be designed to afford such functionality, whereas items or colors used for esthetic appeal should be positioned and tailored in a manner that won't drive the users to mistake them for elements of information and visa versa. Finally, not all information spaces are complete or closed sets, some of them remain open or dynamic while others suffer from non-rectifiable gaps. Gaps in information spaces should be visualized and made noticeable for the users in order to ease their identification and isolation. Some visualization schemes have chosen to abstract such gaps in favor of the overall presentation or the look of the visual metaphor, but it's rather vital for the study of such gaps that the latter be visualized in relational context with the rest of the information space. Finding what is missing in the information space is as important as finding what is actually there.

3.2 Information visualization

The field of Information Visualization is still very experimental par excellence. Numerous attempts have been already made to use the human potential in recognizing, interpreting, and manipulating visual cues without reaching "satisfactory levels". In other words, users or information seekers still find nowadays a number of difficulties in using digital information schemes for information retrieval, or in browsing information spaces with the help of visualization tools. These difficulties are generally inherent in the ways the information retrieval and visualization schemes are designed and the manner that users are bounded to interact with them (Schneiderman et al., 2000). Some work has been done to address this issue from a psychophysical point-of-view by exploring and taking into account the functional aspects of human vision and graphical perception on and their limitations, while other concrete efforts explored ways of redesigning human-information interaction by integrating new interactive methods and devices, and looking at the ways users long to interact with information. Some researchers argued in favor of developing new universal visualization metaphors inspired from or emulated in accordance with a number of familiar natural mechanisms and/or biological phenomena, while others addressed visualization problems only as being case-specific to the information space at hand. In short, it is deducible from an Information Visualization literature review (Card et al., 1999) that a comprehensive scientific approach to the issue of visualizing information spaces doesn't really exist to this day despite a large number of isolated successes on designing Information Visualization schemes for specific cases or specific information spaces.

Works mainly led by a Ben Schneiderman, Catherine Plaisant, and others have been attempting to define a broad taxonomy for information visualization interaction practices and design. Such taxonomies are starting to integrate user needs and usage context within information visualization schemes, opening the door for developing interactive information visualization schemes for complex information. The gap between GUI design and information visualization metaphors has been closing, and the application of visualization and interaction techniques in new domains such as E-learning seems to provoke several challenges that usually fall outside the realm of main concerns in information visualization research.

3.3 Interaction

The efficiency of tools directly derive from the ability of humans to assimilate them and work around them, with these applications and schemes tailored in respect to the human cognitive process and taking account of its limitations and powers designers can hope to maximize their utility. In general, visual tools draw heavily on knowledge and experience from cognitive sciences and psychology since the efficiency of the medium upon which rests the interaction between users and the information visualized is highly dependent on the cognitive abilities of humans to correspond with computers through visual cues and artifacts (Cleveland and McGill, 1984). In particular, a discipline within psychology, called psychophysics (Stevens, 1961) argues on the biological configuration of the human eyes and brain to absorb, comprehend, and transmit sensory information such as visual and acoustic properties to name a few. Here, designers of visual tools took two different routes or approaches to address the matters behind the limitations and the characteristics of the human biological sensors. While some thrived to understand how the human sensory equipments work and tailor visualization schemes accordingly, others like S. Mann went to explore how to augment the human sensors with intelligent hardware to increase their capacities (Mann, 1998). In this report, we will address the viewpoint of the first class of scientists since we believe that their approach is more practical in view of the current status of technology inhibiting the use of intelligent sensory hardware based on poor or erroneous behavior or cultural barriers alike (Kolb, 2005).

First of all, to what concerns psychophysics, it has been widely argued that limitations on the humans' abilities to capture, identify, and classify sensory information exist. Such limitations have been approximated according to the nature of the sensory information transmitted to humans, the composition of these sensory information in terms of unitary properties such as pitch and tone to what concerns sound for example, and the environmental properties under witch such transmission and deciphering are taking place such as time factors (transmission time, time between transmissions, and time given to human subjects to reflect upon the information transmitted). A good summary or overview of the results psychophysicians reached can be found in Miller's paper on the limitations of human sensors (Miller, 1956). Since the purpose behind visualization schemes is to facilitate interaction with and assimilation of large information spaces in little time, it is vital for such quest to be designed under the limitation of human sensors. A visualization that overwhelms human sensors will only frustrate its users whom will become largely prompt to erroneous behavior and discontinuity with the information's context. The failure to take human physiological properties into considerations may strongly be the explanation behind the failure of many complex (or sometimes simple) information schemes to achieve high usability levels.

Interactive visual tools, like the majority of software applications, may be dependent on the human environment in which they are deployed. In some environment, users don't have the time to decipher complex information metaphors designed to represent large information spaces, while in others users may be totally dependent on their interaction with the information application to succeed in their work or quest. In short, understanding the properties of the targeted human environment and how humans behave psychologically in that environment becomes an issue of moderate if not high priority to the designers of visualization schemes and to those developing software application in general. However, being a special type of software, informative applications are not generally built only to cover the users' need for a set of functionalities and are rarely developed to pertain to a closed set of tasks. These applications rather aim at making information spaces accessible and manipulative, and hence shed more importance on understanding the behavior of users within and around the information spaces visualized. In other words, the freedom provided to users through the accessibility of information must not hinder the usability of the informative applications since users, after being provided with the right access to information spaces, should be allowed and supplied with the right tools and guidance to perform whatever task they have in mind. Hence we may argue that cognitively speaking, cognitive considerations should be made to provide an easy access to information and afford freedom of manipulation by design whenever allowed and possible.

Hence, the structure of information presented should always pertain to low requirements in cognitive effort necessary for the absorption and manipulation of information. In general, information metaphors should rely on familiar notions and abstraction signs to facilitate their assimilation, an idea here would be to inspire from the nature of the deployment environment and its surroundings. The adoption of familiar metaphors eases the required cognitive load and lowers the learning curve of users who base and draw from previous experiences and knowledge about those metaphors in manipulating them in a new environment to retrieve and browse information, and hence reduce the users' learning curves. In addition, formulating a good understanding of the users' behavior around certain sets of information spaces would facility the design of schemes that afford some beneficial actions and inhibit others. For example, one might deduce from a behavioral study of stock market analysts that the latter heavily investigate stock numbers displayed in red and could develop a stock market visualization around such knowledge in a manner where the color red is used to suggest further zooming and investigation within the visualization.

In appendix 3.2 we present the results of our first explorations on how current interactive tools can be applied to the field of curriculum development programmes. Our first approach is based on graph visualizations of CDPs. It became clear that these graphs do a good job in visualizing the structure of programmes, yet information such as time, competence level and granularity is hard to visualize in this manner. For this reason, we moved on to more attractive visualizations that invite exploration and navigation. Landscape metaphors, with cities replaced by learning objects, and the Kartoo visualization tool provide a better job at this point. In order to correctly display time lines and interdependencies, we also explored the use of Gantt charts.

3.4 Scenarios for Curriculum Design

To clarify the context of use of the curriculum planning tool, we created two distinct scenarios. The first scenario is a PhD curriculum including 2 years of seminars and courses plus a period to complete the doctoral dissertation. The second scenario is an e-learning course on digital cinema designed to develop competences related to the virtual sets production process, including pre and post production. It is directed at the television and cinema industry professionals, principally television and cinema professionals, visual effects students and practitioners, stage designers. The two scenarios are described in detail in Appendix 3.3.

3.5 State of the Art

In appendix 3.1 an analysis of three current curriculum editors, all part of larger Learning Management Systems, is presented. Based on the analysis, we built a comparison table of functionality offered to the e-learning curriculum designer. The categories are based on the main requirements we perceive as important of the design of a CDP editor.

	Connecting learning object	**Overview of prerequisites requirements**	**View of follow-up, choices, options**	**Modular composition**	**Nested composition**	**Load/save paths**	**Explora-tion/na-vigation**
LAMS	Yes	Yes	Yes	No	No	Yes	No
Moodle	Only possible in a chronological order	No	Yes	A topic can contain different activities or resources	No	Courses can be restored from backups	No
Learning Design Editor	Very sequential	Yes	No	Yes	No	Yes	No

The table reveals two important aspects of the state of the art in e-learning curriculum design systems. First, current tools do not allow to mix sets of path together like it is supposed by modular composition. Plus they do not reveal the importance of relations between activities or courses. To the extend of our knowledge, there are not e-learning tool for curriculum designers to paths upon courses, module or programmes. Second, intuitive exploration and navigation has not been pursued as an objective. No visualization metaphors have been explored to reveal the complex information as the one carries by CDPs.

We believe that these two aspects must be pursued in the design of next generation e-learning curriculum editors.

3.6 Conclusions

In this section, we looked at the challenges for the design and development of effective visualization and interactive system for information systems. We performed an overview of the literature in order to scope our work around high-level scenarios of curriculum design.

In summary, our background research and first explorations have taught us that it is not at all trivial to provide curriculum designers as well as learners with dedicated support for visualization, navigation and exploration of curriculum development programmes. We need to build upon the current design knowledge and take general GUI design challenges and issues in information visualization into account. The first explorations show that this can be achieved by making use of (concepts derived from) existing visualization approaches. However, the big challenge will be to find a set of suitable metaphors that will be used in the whole system. In addition, we will need to provide the users with a well-chosen set of complementary views on the information space. A state-of-the-art analysis of current curriculum editors shows that these aspects, which we think are absolutely necessary, are not yet covered by these systems.

In the next chapter we present three prototypic tools that represent our first attempts to fill this gap.

4 Prototypic Tools for Curriculum Planning

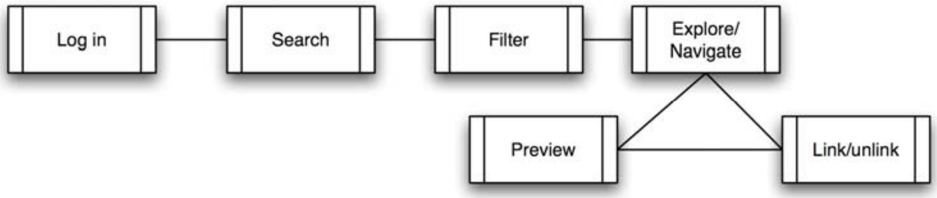
The previous chapter showed that currently no tool is available providing sufficient support for curriculum planning. A tool for curriculum planner should allow E-learning material authors as well as learners to create and edit lifelong and individualized learning programme. It should provide an overview of prerequisites, requirements and metadata of each learning activity. Additionally, it should visualize the relevant learning activities to connect to another activity by utilizing a navigation service. What such an interface should look like, is the issue of this chapter: we introduce three first implementations offering the above-mentioned features. The first prototype, a CDP Composer Tool, applies our research in the area of visualization of learning paths. A second prototype applies the theoretical model of a learning path and makes – beyond others - use of the prerequisite relationships between learning activities and also uses metadata of learning activities such as the time when an activity is held. A third implementation is presented which applies planning algorithm in order to assembly a list of learning activities that leads to a certain learning goal.

4.1 Prototype of a CDP Composer

As discussed earlier, we are challenged to invent powerful information visualization methods, while offering smoother integration of technology with task. This section summarizes our prototype facing this difficult challenge in the context of e-learning. In Appendix 4.1 we present the simplified models and schemas that support the definition of competence development programmes and learning paths. We exemplify our approach by a scenario in Appendix 4.2 that describes how a learner called Erica plans a learning path for the learning goal Virtual Sets.

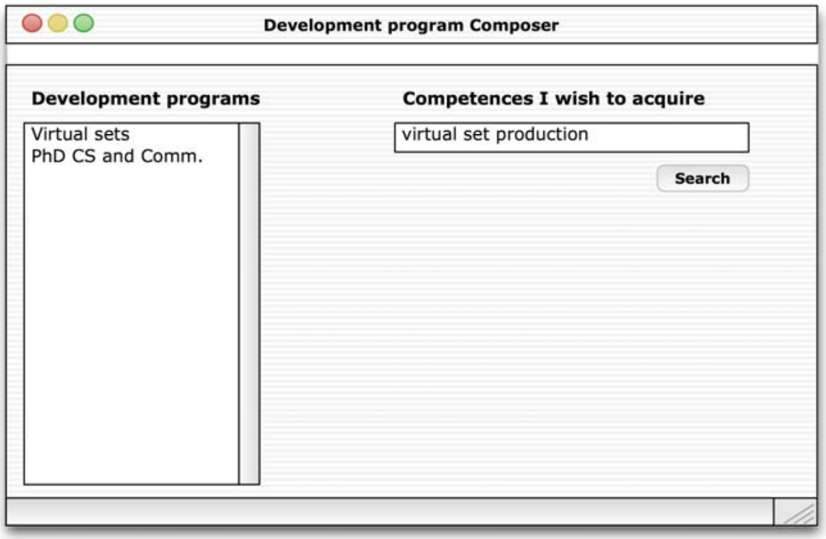
We started our exploration with the idea of the integrated system that should merge all the views on a CDP in one. A CDP is about relation and basically can be viewed as a graph. As a model to represent a CDP we introduce the so-called Representative Dependency Matrix (RMD). For more details about that data structure we point the reader to Appendix 4.3. Yet, there are dimensions such as the time and competency level, multi-scale proximity, granularity that do not well carry with a graph view. Below are figures representing an attempt to render the dimension of time, competence acquisition and granularity of a learning object. In summary, our approach uses a first 2D maps visual representation for content navigation and exploration and learning path edition. Second it the representation of the relations in time with the units of learning relies on a basic Gantt chart. The whole information visualization system is an integrated system with high interactivities (contextual on the maps). It uses a well-known metaphor of space to get detailed information on a selected item (unit of learning). We used GUI design studio (/www.carettasoftware.com/gds/index.html) to develop an interactive interface featuring the main interactions and capabilities.

The task model of the system follows the visual information seeking mantra: Overview first, zoom and filter, then details-on-demand. Practically, the flow of use of the system (i.e., tasks model) is as depicted below:

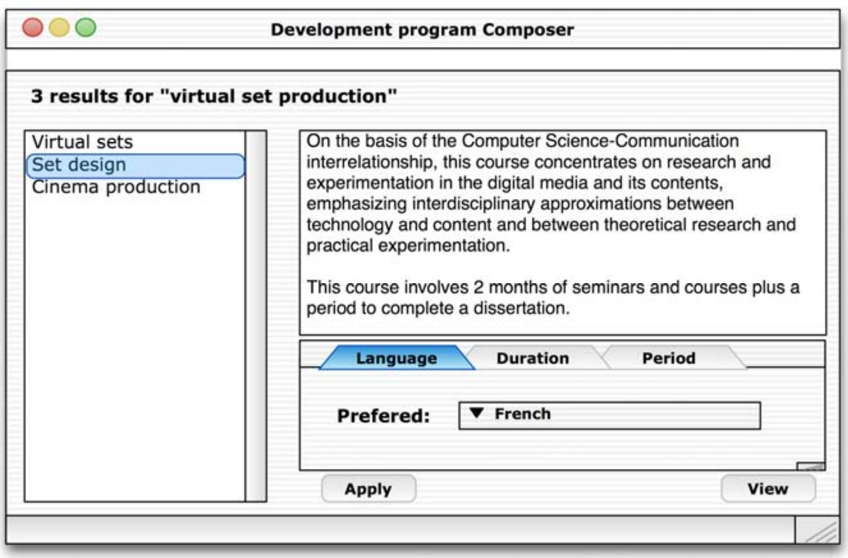


A typical scenario can be as follows:

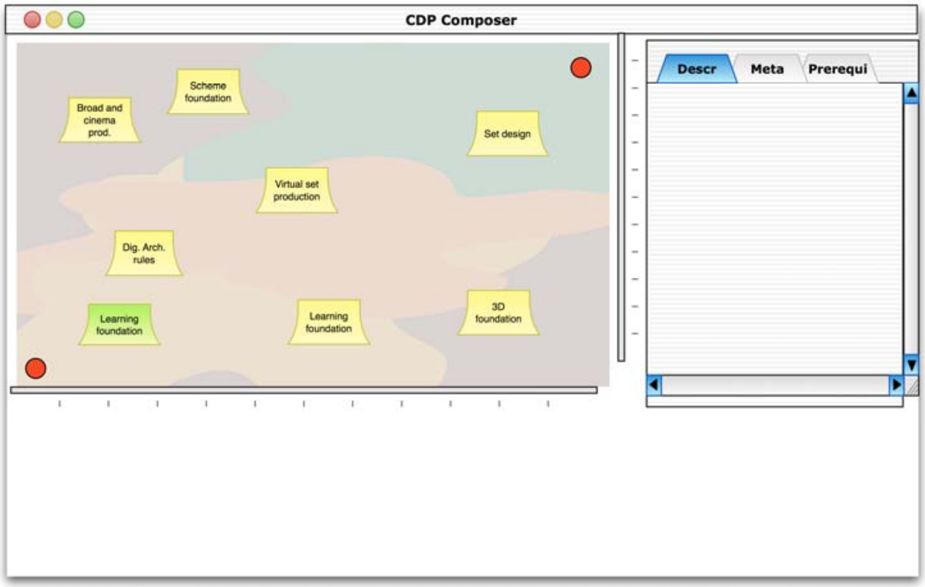
1. Set competences to acquire: first the curriculum designer should have the ability to set the goal (i.e. the expected acquired competences) the composition of a CDP should achieve.



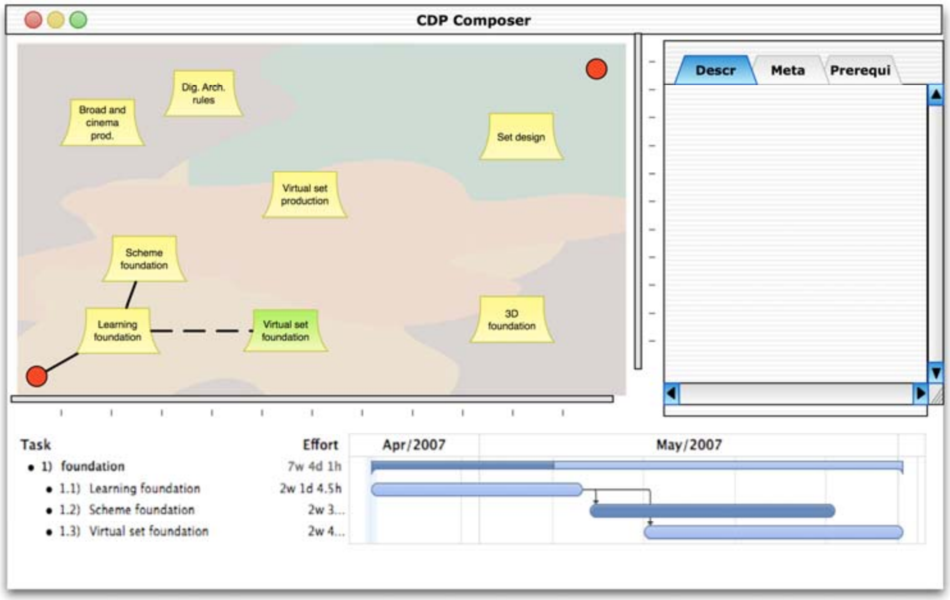
2. The system retrieves and displays the relevant UoL and CDP. Filtering can be performed by selecting metadata information such as language, duration and periods.



3. The curriculum designer can explore the visualized items. Aggregated UoL or CDP are displayed to give access to a lower granularity of the programme. For example, a mouse-over the item shows the metadata of the CDP. Proximity is calculated from a Representative Dependency Matrix as explained in Appendix 4.3. The difference colors represent the different phases and steps of the programmes.

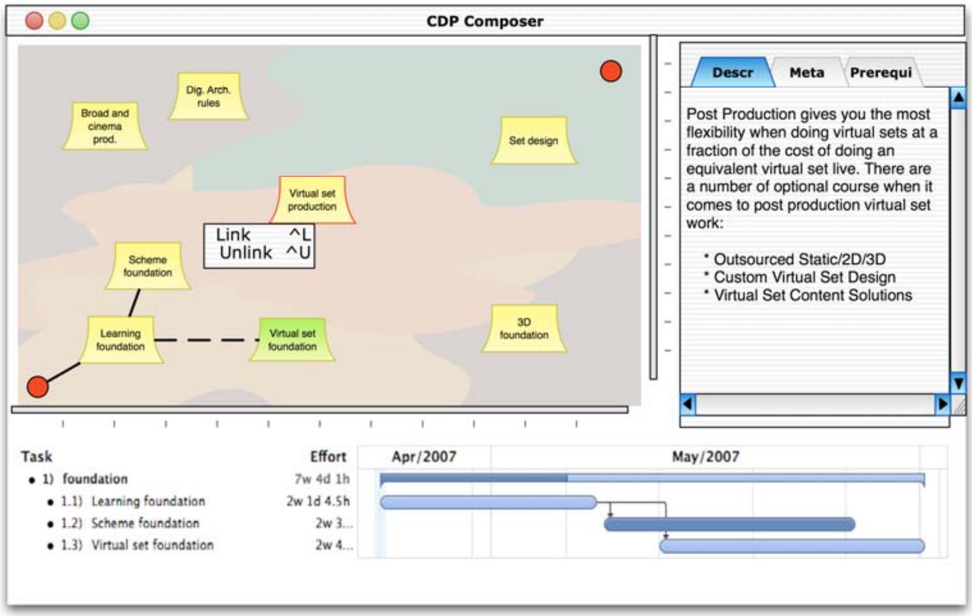


4. The curriculum designer can link the items with a value (e.g. prerequisites, optional). The items represent 3 types of granularity of learning object: modules, courses and programme, with a "module" being the atomic level. There are 2 type of relationships among items, prerequisites (straight line) and optional.



5. View of description and metadata (selecting). Each learning activity can be selected to gain further information on its nature (e.g. description, metadata, prerequisites).

6. Linking is done with a direct direct-manipulation approach. Use of a contextual menu on the visualization.



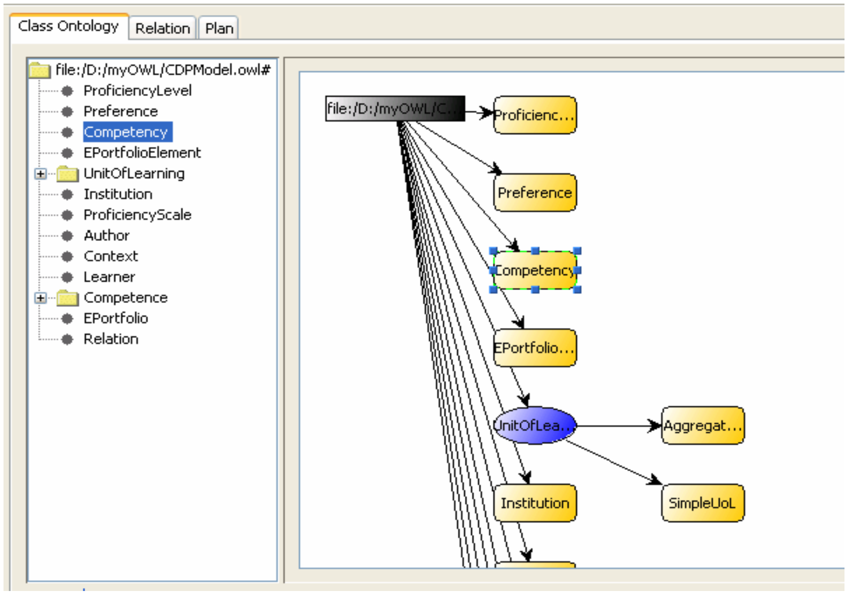
4.2 Graphical Curriculum Planning

In this section we describe a tool for planning a curriculum based on the learning path description models, as they are described in Appendix 5. The implementation consists of an OWL representation of the Competence Development Programme Model, of the Domain Model, and the Learner Model. Sample instances based on real university courses have been added to the model using the open-source ontology editor Protégé. The models where also used for experimentation with visualizations and query mechanisms in the Java Eclipse framework, making use of the Jena2 Semantic Web Framework. More details about the implementation are also to be found in the Appendix 5.

Making use of the JGraph graph visualization toolkit, several visualizations of the ontology have been created. First, there is the *class ontology*, which provides an overview of the various classes in the ontology, and details on demand. Second, the class instances and their relations can be visualized in a *relation graph,* which provides several manipulation possibilities. Third, a *query interface* with visual output may be used for answering questions on the domain. Additionally, an interactive *curriculum planning* interface has been created, which provides visual feedback on the possible elements to add to a curriculum. Recently, the planning facilities have been extended by a Schedule Panel providing the learner with an overview showing which course is available at what time. These visualizations are described below.

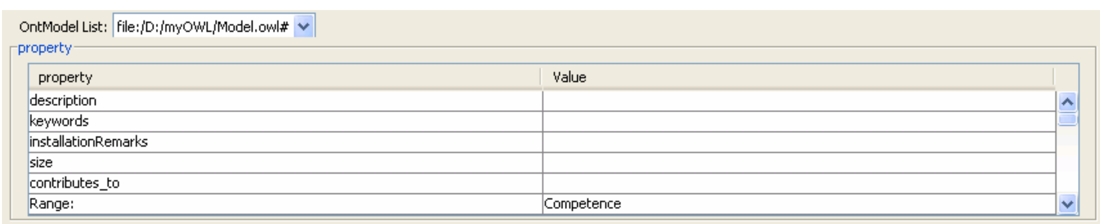
4.2.1 Class Ontology

The class graph provides an overview of the class ontology. This visualization is synchronized with an hierarchical tree. This has as an advantage that the whole hierarchy is visible at once.



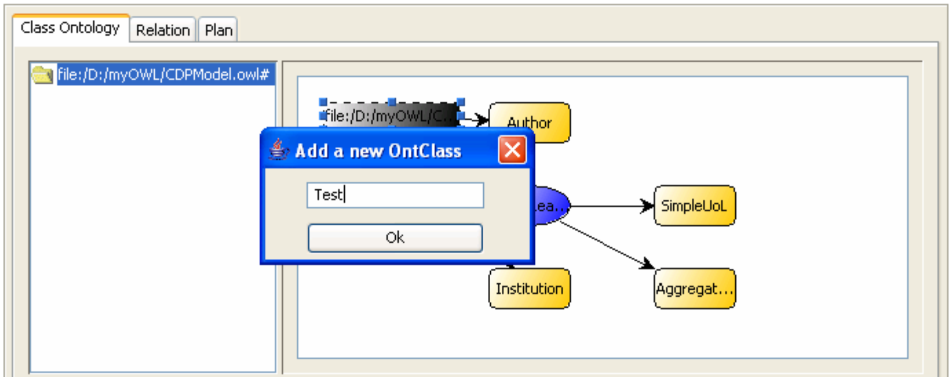
Class Ontology

Upon selecting a particular class, the property panel shows all properties of this class.

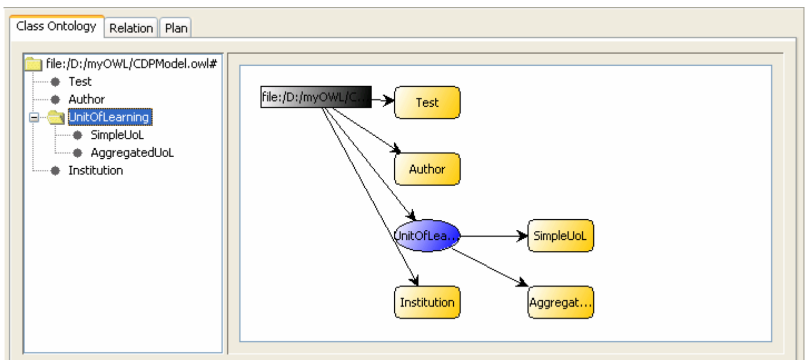


Properties of a Unit of Learning

Right-clicking a cell brings up a pop-up menu, from which one can choose to add, edit or remove a new class or instance. In the figures below an example is given on how to add a new class.



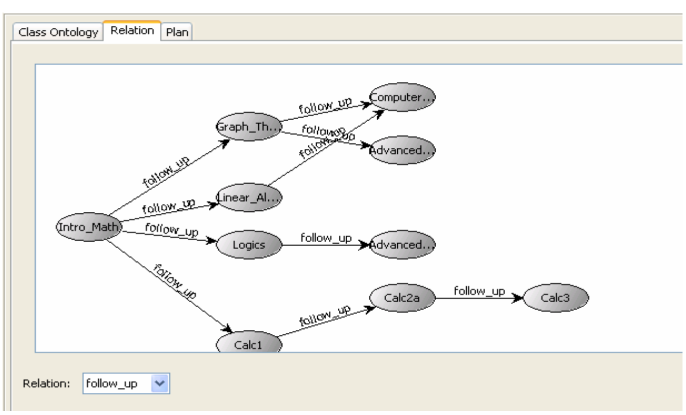
Adding a new class (1)



Adding a new class (2)

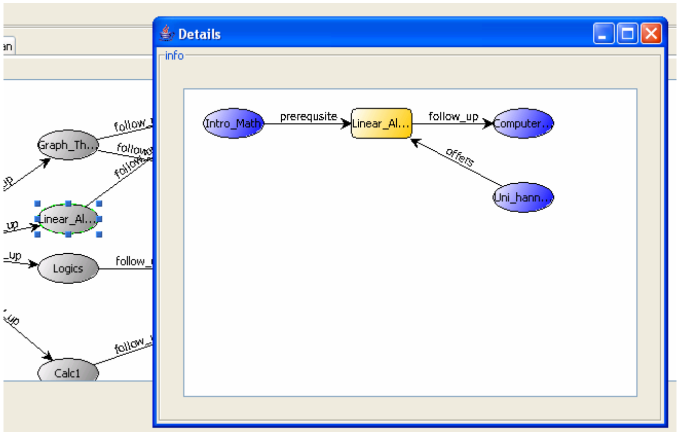
4.2.2 Relation Graph and Instance Graph

The relation graph and instance graph provide two different perspectives on the instances in an ontology. In the figure below, all classes and one specific type of relation ('follow-up') is displayed. The relation to visualize is selected using a combo box, which provides an overview of all available relations.



A Relation Graph

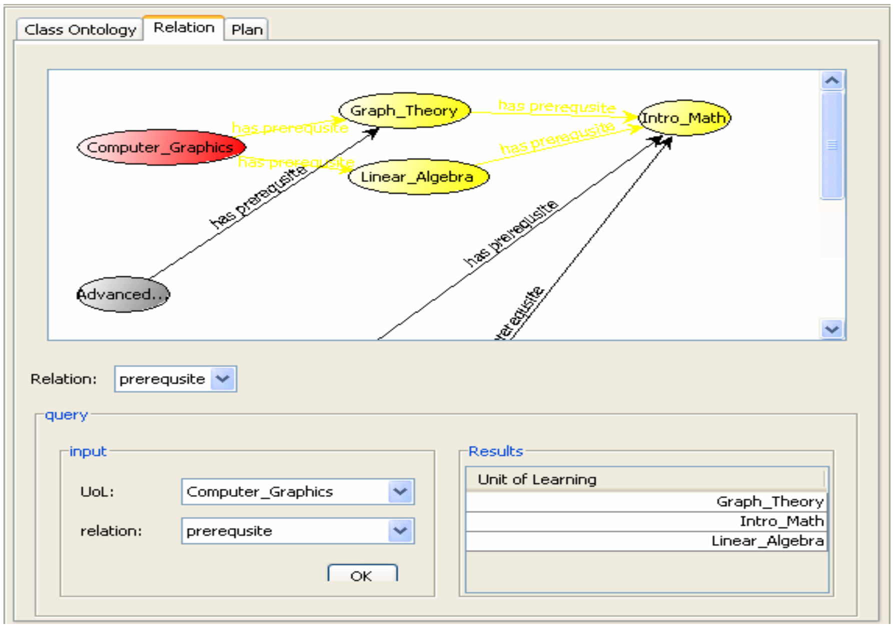
Upon clicking a specific instance, a pop-up graph shows all relations leading to and from this instance. In this particular example the learning unit 'Linear Algebra' has a prerequisite 'Introductory Mathematics', a follow-up 'Computer Graphics', and is offered by the University of Hannover.



The Linear Algebra instance and its relations

4.2.3 Query Interface

Suppose that for a sufficiently large domain, one wants to know all prerequisite learning units for one particular learning unit, including the prerequisites of the prerequisites. This can be achieved using the query interface. One selects a subject, in the example of the figure below Computer Graphics, and the relation 'prerequisite'. Now the subject is colored red, and all prerequisite courses are marked yellow. Thus far, the query interface only facilitates these simple kinds of queries. Future versions will facilitate more complicated queries by combinations of conditions.



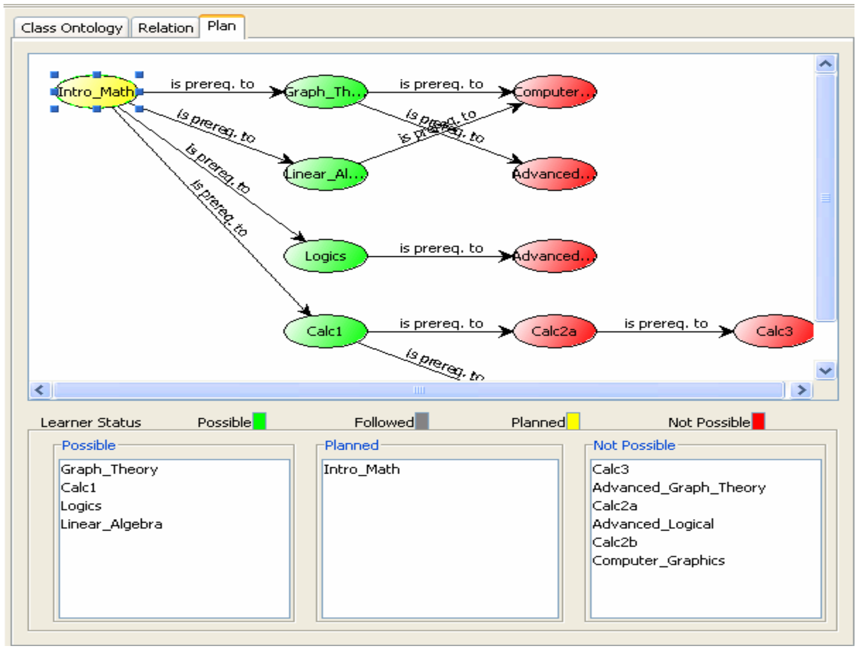
Prerequisite Courses for Computer Graphics

4.2.4 Curriculum Planning

Perhaps the most important visualization from a learner's perspective is the *curriculum planning interface*. It allows the learner to explore all possible options for creating an individualized curriculum, with visual feedback on what already has been planned and the actual options. A simple color-coding mechanism is provided for this purpose:

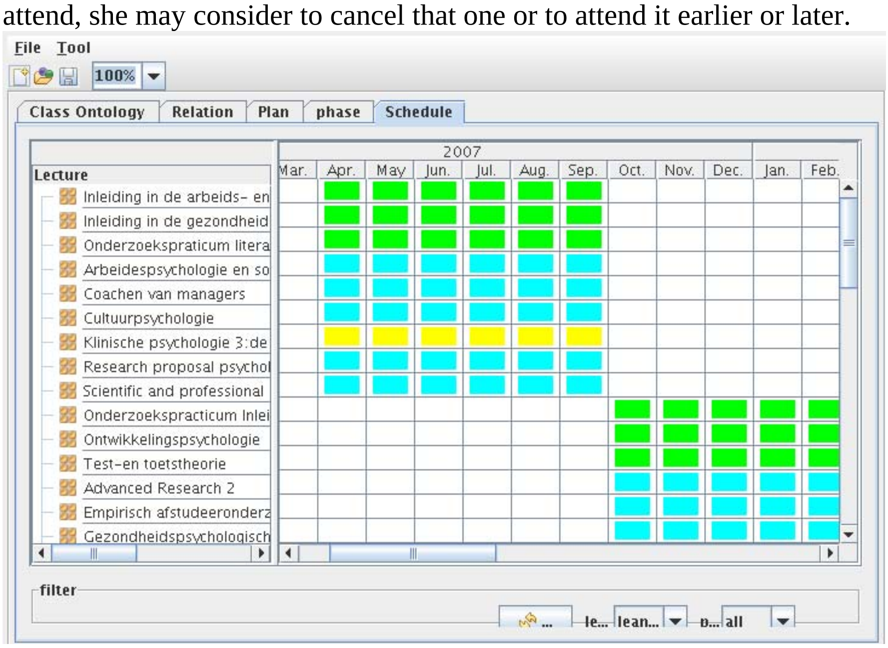
- *Followed* courses are marked grey
- *Planned courses are marked yellow*
- *Courses that may be followed, given the current selection, are marked green*
- *Courses for which prerequisites fail, are marked r*ed.

Upon selecting a course, the color coding is updated: the selected course is marked yellow, and all courses for which the prerequisite conditions are satisfied now, will be colored green. Upon removing a course from the curriculum planning, all courses for which the prerequisites are not satisfied anymore, are colored red. If one of these courses had already been planned, a confirmation dialog appears.



4.2.5 Schedule Panel

To provide the user with an informative overview, a schedule panel has been added to the visualization tool. Since planning a course can not be independent from the term the course is offered (e.g., a semester or trimester) it is important for the learner to get an overview of which of his planned courses he can attend first. From this she may conclude that attending another course at a time where not too much of her courses are offered may be reasonable. Or, vice versa, if the schedule view makes obvious that one period is overloaded with courses the learner plans to attend, she may consider to cancel that one or to attend it earlier or later.



The Schedule Panel

4.3 Algorithmic Curriculum Planning[1]

In this chapter we describe the implementation of a Curriculum Planning Service for building personalized paths in a space of semantic learning resources. The service applies reasoning on semantically annotated data about courses held at the University of Hannover for planning personal curricula. The curricula are personalized with respect to the learner's context, i.e., current known topics and her learning goal, i.e., the topics she wants to learn.

The reasoning is realized by means of actions techniques. We provided a semantic annotation of the set of courses with preconditions and effects. In fact we interpret each course as an atomic action, on the basis of prerequisites (what the student should know for understanding the course contents) and effects (what the student is supposed to learn by attending the course). Given such input data, the Curriculum Planning Service returns a set of possible personalized curricula, i.e. a set of linear plans. Then a user interface is in charge to present these plans to the user as personalized sequences of courses to attend for reaching the desired learning goal.

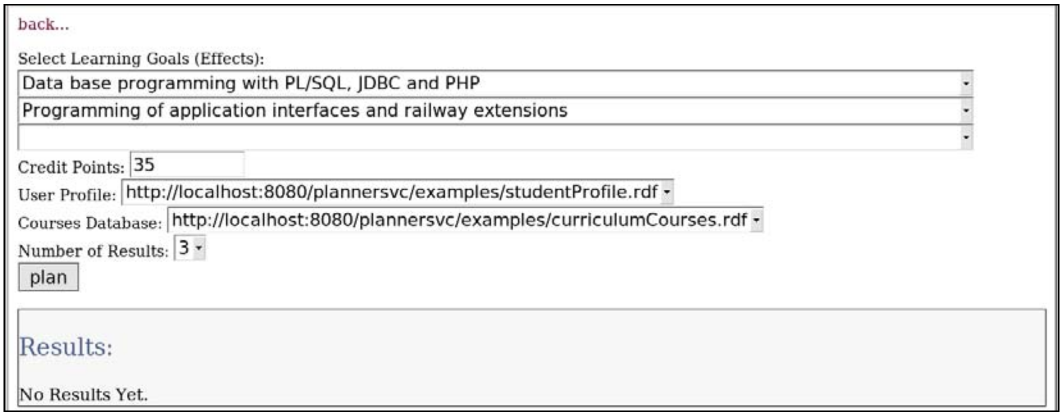
4.3.1 Reasoning on Metadata

The metadata describing the properties of all the learning activities to be assembled is stored in an RDF document. Given this semantic annotation comprising preconditions and effects of the courses, classical planning techniques are exploited for creating personalized curricula. The curriculum planning task is accomplished by a reasoning engine, which has been implemented in SWI Prolog. The interesting thing of using SWI Prolog is that it contains a semantic web library allowing to deal with RDF statements. An RDF request document contains a) links to the RDF document containing the whole information about the available courses, b) the user's context, c) the user's actual learning goal, i.e., a set of knowledge concepts that the user would like to acquire. The knowledge concepts – or topics - are taken from an ontology representing the structure of a certain knowledge domain. Given a request, the reasoner runs the Prolog planning engine on the RDF graph comprising all the courses annotated with prerequisites and effects (beyond other metadata). At the end of the planning process an RDF response document is returned. It contains a list of plans (sequences of courses) that lets the learner achieves her learning goals with the given profile. The maximum number of possible solutions to compute can be set by the user in the request document.

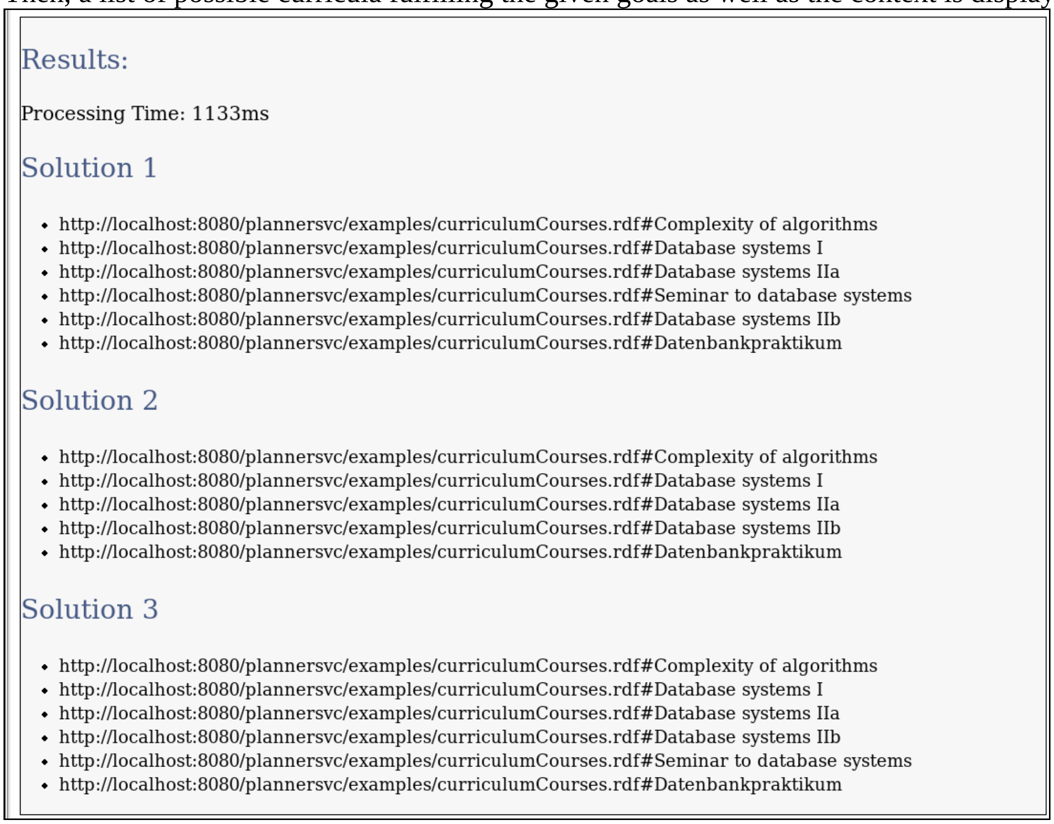
4.3.2 Prototype and Experiments

As a proof-of-concept, we created a simple Visualization Servlet (available at `semweb2.kbs.uni-hannover.de:8080/plannersvc`). The service provides a planning tool for the Computer Science Curriculum at the University of Hannover. The figure below shows a simple html form which allows the user to select learning goals as input for creating the curriculum sequences. Pressing the plan-button sends a request to the Servlet powering this interface, and an RDF request document will be created. This document will be used to invoke the web service. The test data consists of 65 courses with 390 effects and 146 preconditions. Given the query depicted in the picture below the RDF response returned by the planning component is parsed by the servlet.

[1] The base research yielding the results used in this section had been carried out in cooperation with the EU-Project REWERSE (Baldoni et al., 2006).



Then, a list of possible curricula fulfilling the given goals as well as the context is displayed:



4.4 Conclusions and Future Work

The three prototypes presented in this chapter serve as a basis for a forthcoming final implementation. The first prototype solves first challenges of visualizing learning programmes. In the second prototype we exploit the structure of the CDP models available as an ontology. The third prototype offers means to algorithmically find a learner-specific learning path that guaranties for the learner reaching her desired learning goal.

With respect to an overview in the state of the art in information visualization and interaction in the field of e-learning curriculum editors given in this chapter and the first interactive mockups of prototype of our CDP composer, some issues for future work raise in the area of visualization:

- Understand the limit in the granularity. In other words: how could a visualization handle scale-free units of learning and prevent a keyhole effect.
- For exploratory search (student and admin) it is not always clear what they are really looking for. What happens when it gets too cluttered? Find ways to provide valuable filtering.

The Graphical Curriculum Planning Tool will be improved in terms of usability and also concerning the features. In order to help the learner with composing a learning programme by proposing possible plans matching her learning goal, we will integrate the algorithmic curriculum planning into the tool.

As future work, the algorithmic curriculum planning will be extended in several dimensions. On the one hand we are planning to extend the ontology of the topics. This more complex structure will be exploited to make the planning more adaptive to the domain of the courses. On the other hand, we are going to integrate preference handling (as described in Section 5.3) into the planning process, so that the user's preferences can be taken into account. The planning algorithm can also be integrated into the curriculum visualization tool in order to support the learner with recommended plans suitable for his context and learning goal.

In fact, the main issue of future work will be the integration of the concepts of each of the three prototypes that turned out to be successful. From the whiteboard design and the graphical curriculum planner it becomes clear that the system needs to provide functionality for:

- An overview that allows for the provision of details-on-demand
- Both support for querying and selection, and exploration of available items
- Graphical feedback and drag-and-drop functionality for linking items
- Different related overviews for subsequent steps (for example, first selecting the constituent parts of a curriculum, then preparing the concrete time schedule)

What these prototypes clearly clack, is a strong metaphor. Which metaphor to choose, is – as mentioned in chapter 3 – topic of ongoing research. Within the context of the TENCompetence domain studies, as well as by further exploiting the scenarios sketched in this deliverable, we will design and evaluate various alternative metaphors.

In addition to the visualization engine, algorithmic support is needed for correctly representing the aspects of the information space that are relevant to the user. In order to relieve the user from information overload, algorithmic tools for curriculum planning – as presented in section 4.3 – are needed. For the learner, specific types of adaptivity are needed. In the next chapter we describe two adaptive concepts that are suitable for this purpose: a *positioning service* that identifies the learner's position in a curriculum development programme, and two *navigation services* that allow the learner to plan the activities needed to move from the current position to the desired competence level.

5 Positioning and Navigation Services

As all learners who enter a network of lifelong learning have their own expertises, goals and learning styles. It is a challenge to match the individual characteristics with the possibly vast variety of learning content. One of the main goals of the system is to provide learners with selections of material that fit their background and learning goals, and not to force them to follow one predefined programme for each competence that they want to achieve. This implies that the system should be able to generate individualized programmes, and to support the learners in their progress. In this chapter, we describe two services providing solutions for that problem:

- a *positioning service* mapping learner characteristics – as received by an e-portfolio or by a personal competence development plan – onto learning programmes which consist of learning units in a learning network.
- a *navigation service* generating or adapts a programme, based on the individual learner position, needs and preferences;

So far we have carried out extensive background research into suitable techniques and models for navigation and positioning services, which led us to believe we would best be helped by a combined strategy, using both bottom-up and top-down, both ontology and content-driven information, both social- and information-based recommendation techniques. Preliminary services have been developed and have been tested during an experimental field study in the domain of Psychology from October 2006 to March 2007. This chapter describes their general concepts, system design, implementation and results from this study, together with plans to enhance them in the future (during the 'Usability' phase). Additionally, we present recent research results in the area of database retrieval. We applied preference-based search to the selection of learning activities. This technique allows for a exploitable representation of learner preferences and uses this representation in order to select learning activities which are optimal for the learner according to her preferences.

5.1 Positioning Service

In a lifelong learning context a learner may change his contexts and environments several times. When entering his new context he can have prior knowledge for the domain or network he has chosen to develop his target competences. Traditionally this problem is addressed through a process called Accreditation or Recognition of Prior Learning (APL/ RPL). In this process domain experts study documents that have been submitted by learners who apply for exemptions for a study programme. The result of this process is an individualized curriculum where redundant activities have been exempted. In the learning networks context we are researching methods and tools to support this process for Technology Enhanced Learning. The positioning service helps a learner to find a starting position inside the learning network. To deliver these results we conducted a background research and formulated a research agenda for solving this problem depending on the given data which are available in the learning network (Kalz, van Bruggen, Rusman, Giesbers & Koper, 2007). Some students may enter with a very detailed and highly structured profile while others may enter a learning network only with some documents they have produced during their prior education. In the first preliminary prototype version the positioning service focuses on the analysis of documents in the learner portfolio. To chose the learning activities inside the learning network the positioning service needs to know the goal of the learner. Here we assume that the relation between a learning activity and a goal is whether given beforehand in a formalized curriculum or this relation can be derived from activities by former learners. Based on these learning experiences – shown through products in the profile – the positioning service produces a correlation list related to the content of the learning activities the learner has chosen to reach a learning goal. Depending on the policy of the current learning network, these correlations are taken into account when the navigation service produces an individual curriculum for the learner or recommends the next best step.

5.1.1 Applying Content-based Techniques

The analysis of the curriculum a learner has already attended when accessing a learning network is challenging. For the first release of the service we focused on researching content-based techniques for prior learning assessment. For this purpose we analyzed several techniques to calculate the similarity of documents like *Latent Semantic Analysis* (LSA) (Deerwester et al., 1990) or *Reduced Rank Vector Models*. For details about these techniques we point to Appendix 6

5.1.2 User Study

To research the use of *Latent Semantic Analysis* and *Reduced Rank Vector Models* for prior learning assessment we conducted a study in an introductory psychology course / learning network at the Open University of the Netherlands. For the latent semantic space we collected additional material from other psychology books and material from the Dutch Wikipedia. For the learner profiles we asked students to submit material that can be taken as a proof for prior learning experiences for this specific course. The submitted material has been processed and analyzed – preliminary results have been presented during a recent workshop (Kalz, van Bruggen, Giesbers & Koper 2007).

The preliminary results of the first analysis in the introductory psychology learning network were promising because the service gave results that have had a sufficient discrimination between the students and between the documents for the students and learning activities in the learning network. Although there are several examples that look very promising for our application the final evaluation has not been done yet. We will conduct this evaluation through an expert validation in the near future.

5.1.3 Discussion and Future Work

As a next step we will have to adjust and restructure the existing collection of tools for positioning towards an integrated web service that offers a usable API (the concept of this API is in the Appendix 6). We will also need to further evaluate the results from the analysis of the learner profiles and compare them to the decision of experts. Since this part of the project focuses on the use of unstructured data like content in a learner portfolio the project will be extended in the next cycles to more structured data like metadata and ontologies.

Positioning a learner in a learning network for lifelong learning is a complex task by itself and this is further complicated by conditions that prevent any simple mapping of learner profiles and competence descriptions onto the educational resources. The two most extreme situations that we considered are the clearest: (1) no competence descriptions inside the learner profile and the programme and (2) competence ontologies in the learner profile and the programme.

In the first case a content-based approach is the one to take. The content-based approach to the positioning problem has the advantage that it can be used for positioning right now, where most learners do not have structured description of their competences. The drawback of the approach is that it focuses only on textual content. The success of the positioning process is dependent on the amount of text the learner can provide in relation to his educational history.

Furthermore, our research will focus on three different cases: content-driven, metadata-driven and ontology-based. For the first case we have applied our theoretical results to a real-life example from a psychology course of the OUNL. For the metadata case there are several options. If possible we will enrich the existing learner profiles with metadata and take also into account several metadata-like information about the introductory psychology course. Another option would be another experiment in a different domain where metadata are given. The third study will explore a situation where very structured data like competence maps or competence ontologies are given on both sides (learner profile and competence development programmes). Su (2002) presents several different situations for ontology comparison: The single ontology approach where all information sources are related to a unified global ontology, a multiple ontology approach where every information source has its own ontology without a shared vocabulary and a hybrid approach where all information sources have their own ontology but they use a unified shared vocabulary. In an ideal situation every learning network could share a common understanding of the competences needed for successful running through a competence development programme based on ontologies. In this case positioning inside a learning network can be based on the relations between a domain ontology and the competence ontology (Pozea & Harzallah 2004). It is still an open question how an "asymmetrical positioning" (Kalz et al, 2006) could be addressed, where different data sources are compared.

Currently there is no direct interaction between the positioning service and the learner through the TENCompetence client. Nonetheless there are several options to inform the learner about the results of the positioning procedure which will be explored in the next cycle.

5.2 Navigation Service

The Open University of the Netherlands designed a prototypical Personalised Recommendation System (PRS) and evaluated it in a first experimental field study, attended by around 180 students. The PRS recommends most suitable learning activities to learners, by taking into account their personal profile and the (successful) behavior from other (similar) learners. We used a special kind of collaborative filtering technique, called stereotype filtering, and combined this with a simple ontology.

5.2.1 A Hybrid Recommendation Approach

The general concept of the PRS for a learning network (LN) is in line with hybrid recommender systems in other domains. Hybrid recommender systems combine different kind of recommendation techniques to achieve a higher accuracy in their recommendation. Because every single recommendation technique has its own advantages and disadvantages, their is a need to combine techniques to increase the accuracy of recommendations. Using a combination of recommendation techniques is called a *recommendation strategy* (Van Setten, 2005). Recommendation strategies use domain specific or history information about users or items to decide which specific recommendation technique provides the highest accuracy for the current user.
For PRS in lifelong LN it is not possible to simply take or adjust an existing PRS for consumer products (like in amazon.com). PRS for lifelong learning should support the efficient use of available resources in a learning network to improve the educational provision, taking into

account the specific characteristics of learning. PRS in LNs have to be driven by pedagogical rules, which could be part of the recommendation strategy. The recommendation strategy looks for available data to decide on which technique(s) to select for which situation. In Appendix 7 a detailed description which technique has been used in our approach and which way it has been applied.

5.2.2 User study

We established an experiment to examine a first version of a PRS for learners in LNs. The experiment is carried out in the context of the regular “Introduction Psychology” course as offered by the Department of Psychology at the Open University of the Netherlands. 18 study tasks were created on this topic, each linked with specific learning goals and characteristics. An additional study task contained general information (FAQ) about the learning network. Study guidance was provided through the Learning Management System ‚Moodle’ where the study tasks were implemented as learning activities. This restricted collection of formal learning activities from a single provider served as the ‘mini-curriculum’ on which navigation support was provided. The behavior of the learners were tracked, i.e. it was recorded which and when a learner enrolled to a learning activity and when the learner completed it. The learners had to fulfil their personal profile before they were allowed to enter the course. The profile of Moodle was extended with personal learning attributes (study motivation, study time and interest in a specific topic). The experimental group got a PRS, which take into account the learning attributes of their profile (to create similar peer-groups). The control group used the same collection of learning activities and environment but without any recommendation from the PRS.

At the moment where this document was created we were not able to present final results of the experiment, because the data analysis was still going on. But some preliminary results that seem to be promising could be presented.
Figure 3 is an observation of successful completed course per group. It shows that the experimental group (with a PRS) continuously finish more courses successful than the control group (without a PRS).

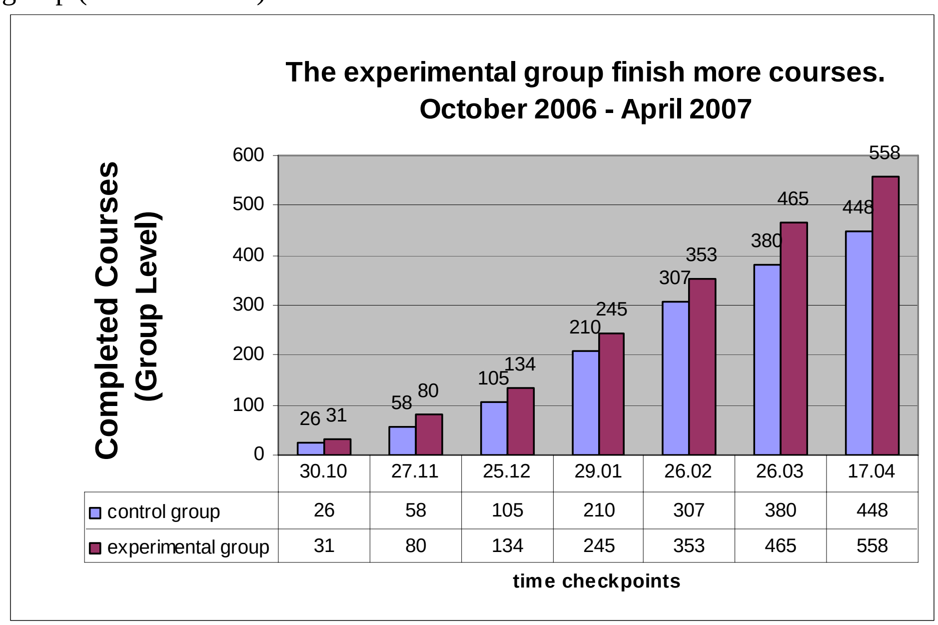
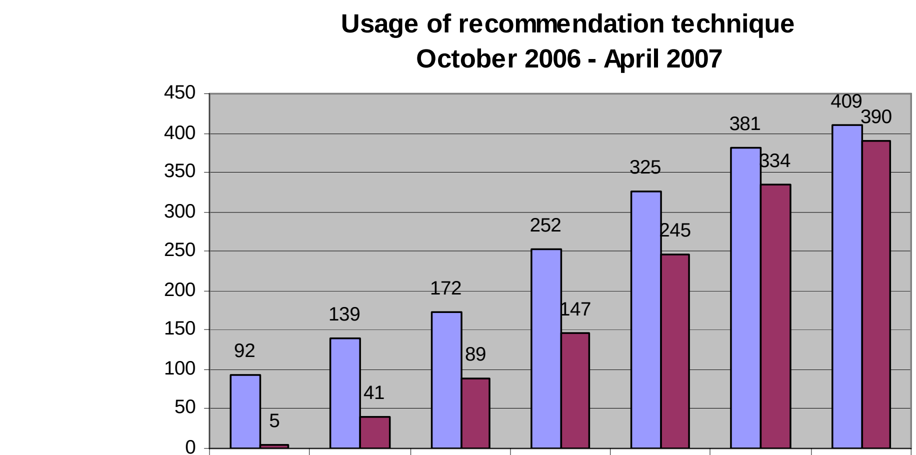


Figure 3: Completion of Courses on the group level

Figure 4 shows which part of the recommendation strategy was used to provide recommendations to the learners. During the first three weeks the cold-start problem of recommender systems was present because there was no entry in the transition matrix. All recommendations in this period were covered by ontology recommendations and no recommendation was given by collaborative filtering. But since the second checkpoint, collaborative filtering has been used more often and became equally used compared to the ontology based recommendations at the end of the experiment.



	30.10	27.11	25.12	29.01	26.02	26.03	17.04
ontology	92	139	172	252	325	381	409
collaborative filtering	5	41	89	147	245	334	390

Figure 4: Usage of Recommendation Technique

5.2.3 Future Work

We want use the results and of the “Proof of concept” study, and extend the results in a second study in 2007 with more learner and learning activity attributes, and with the emergent effect of ‘ratings’. For this purpose we want to simulate a distributed learning network beyond the practical constraints of a field test. Simulations enable us to explore emerging effects of ratings. We want to further investigate the connection between the micro-level behavior of individual learner and the macro-level patterns from the interaction of many learners. The simulation will enable us to observe the effect of the recommender system for different sizes of LNs scalable amount of learners and learning activities. We will monitor how the LN behaves if 800 or 5000 learners are connected and how our recommendation strategy has to be adapted to such circumstances.

The third study will take place in 2008, and will be carried out in the context of a TENCompetence pilot. This pilot study will use an advanced, more flexible personal recommendation system for a learning network in the domain of Health Care. We will implement the system and collect data for the final configuration of the PRS for learning networks. The third study will use the results and outcomes of the first studies, and further elaborate them with mechanisms of ‘free tagging’ (folksonomies).

Furthermore, our research will treat the ‘cold-start’ problem which limits the provision of suitable recommendations. When not enough data are available for any kind of recommendation technique, the recommendation strategy should select technique(s) that (provide(s) the most suitable recommendation ion the current situation. Future research has to analyse which attributes of learners and learning activities and which recommendation techniques perform best. We will incrementally design and test various versions of PRS in consecutive studies.

5.3 Preference-based Selection of Learning Resources

Finding a suitable learning resource is crucial for navigation services. In this section, we show that modeling preferences can yield a valuable support for finding a set of optimal learning resources meeting the learner's preferences. We applied this technique to a preference enhanced search service for learning resources. This preference based search facility can easily be extended to or combined with a recommendation service for learning resources. Search capabilities in educational repositories and networks have been improved in recent years by the introduction of personalization and semantic-based queries. These techniques are typically realized by adding into the query hard constraints representing the user wishes (e.g., from the user profile), that is, conditions that must be fulfilled. Examples of these hard constraints are ``results must be either in English or German and must provide a certification". There are two choices how to incorporate these additional constraints into a given query, both leading to suboptimal answer sets. Either, we use a conjunctive query, i.e., the additional constraints are connected with an 'and'. In this case, the danger is high that we end up with an empty result set because of the query becomes too specific. Or, we add the constraints disjunctively, i.e., all constraints connected with an 'or'. But then, the size of such a result set grows significantly, and will contain many scarcely relevant results.

Typically, a user may want to express that she wants ``courses preferably in English but if there are not, also in German would suffice and which take place on Mondays better than Tuesday or Fridays". These ``preferably" and ``better-than" indicate soft constraints in which a user specifies what she prefers, that is, her wishes as preferences. These preferences can then be used in order to filter out non-relevant results. For example, if two courses are found, both on Mondays and one is in English and the other one in German, intuitively the latter can be discarded since given the same (or worse) conditions, the user prefers English over German. This way, only optimal results according to preferences are returned. This improves the satisfaction of the users and reduces the time they must spend in order to scan large query result sets.

For more theoretical details as well as details about the implementation we point the reader to the whole paper in Appendix 8.

5.3.1 Implementation and Experiments

We implemented a Web Service for preference-based queries called Personal Preference Search Service (PPSS) which can perform preference queries over arbitrary sets of learning resources with an RDF-metadata description.

We have performed experiments with the lecture database of the learning management system of the University of Hannover. That system currently comprises 9829 lectures. As an example, given the following preference query, we show how preference queries optimize the result set and provides the desired learning resources without pruning relevant results or returning non-relevant objects:

Return courses about mathematics. I am interested in readings rather than in tutorials and seminars. If possible, I would like to attend a 90 minutes lecture. 60 minutes are also fine, but 120 *minutes are too long. I like to have the lecture in the morning rather than in the afternoon. Due to the lunch break, noon is not possible for me. I don't want to have a lecture on Friday. Thursday would be my first choice, then Tuesday. Wednesday would also be acceptable and is preferred to Monday, where I am usually still at my parents.*

The result set of this query is shown in the table 3. Obviously, none of the returned courses matches all the desired attributes: the first lecture is held too late, on Tuesday, and it is not a reading; the second is too long, and so on. (Mind that the order in the table does not correspond to a ranking: all six results are equally relevant.) However, concerning all the 64 courses about Mathematics, these 6 results are optimal: the remaining 58 courses are worse in terms of at least one preference relation.

Without the possibility to define preference orders, there are two alternative approaches in classic, i.e., best match search interfaces: The first is to conjunctively connect all preferred attributes and do several queries by going step by step down according to the preference order. This manner of querying returns to few and - in most of the cases - no results. After some queries with no results the user gets frustrated, and even if some results are returned, the user needs to create queries with all different alternatives in order to be able to select the best match. In our current example the conjunctive query yields an empty result since none of the courses in table 3 bear each of the most preferred properties.

Table 3: Optimal courses at University Hannover

Course	Start time	Type	Weekday	Duration	Faculty
Mathematics Exercises	10:00	Tutorial	Tuesday	120	Applied Math
Mathematics (Economics)	09:00	Reading	Thursday	120	Algebra
Mathematics (Geography)	08:00	Reading	Thursday	90	Analysis
Mathematics (Engineers)	10:00	Reading	Tuesday	60	Applied Math.
Mathematics (Chemistry)	09:00	Reading	Thursday	120	Chemistry
Mathematics and Physics	10:00	Reading	Tuesday	90	Chemistry

The second approach is to disjunctively put all the possible desired outcomes into a single query. This query usually returns a huge result set containing the desired optimal courses but also a lot of non optimal results which are dominated by better ones. In our example, this querying yielded 25 courses including courses with suboptimal attribute combinations. By using the principle of pareto domination instead of conjunctive or disjunctive querying, the PPSS reduces the number of results from 25 to 6.

5.3.2 Discussion and Future Work

Although the approach of preference-based learning object retrieval is powerful there are still challenges to face concerning the eliciting of user's preferences. Several solutions for that are out there such as the presentation of representative objects, the user likes or dislikes. Another solution would be the presentation of a suitable interface where the specification of preferences is supported by the system exploiting knowledge about the user. These topics as well as the merging of the preference approach with the content-based positioning and navigation services we consider as future work.

5.4 Conclusions and Future Work

The first study (experimental field study within the domain of Psychology at OUNL) has been completed (October 2006-April 2007) and was reported in this deliverable. The second study is currently in preparation (March-September 2007), and will contain a series of simulations in Netlogo. We will simulate the variables of the first study, but also experiment with variations of these variables and extensions with other variables. We will include ratings by learners and experiment with larger numbers of both learners and learning activities, to better explore the emergent effects in LN. The second study will use user- and item-based recommendation techniques (user ratings) in combination with case-based reasoning (using personal information) in one recommendation strategy. The third study will be another experimental field study in the domain of Health Care, a second cycle pilot of TENCompetence (approximately March-September 2008). An advanced PRS will be based on results from the first and second study, combining most successful techniques in a recommendation strategy. Here we intend to include user-based tagging (folksonomies) and combine this information with attribute-based recommendation techniques.

The results from the preference-based approach are promising for an integration into any kind of recommendation service since this approach helps to select an optimal subset of all possible learning activities. We will do further research in this direction and we will examine how user preferences taken as an additional input into the recommendation process improves the results of the positioning as well as the ones of the navigation service.

6 Summary, Conclusions and Future Work

In this deliverable we have reported the results of the activities carried out in the context of TENCompetence WP7 in the first eighteen months of the project. From our background research, it has become clear that currently there is only limited support for the creation and use of competence development programmes. In particular in the context of lifelong learning, there is the need for tools to support this need. In order to come up with solutions, research has been carried out in several directions. In this concluding chapter, the results and the plans for future work are summarized.

First, we spent effort on the creation of a *learning path description*. This specification should facilitate the creation, sharing and use of curricula, targeted to several types of learners. In chapter 2 we have presented the current state of the specification, which is mainly inspired by IMS Learning Design. In a study in the domain of the OUNL Psychology Course, we have seen that the specification provides sufficient flexibility for our purpose. In addition, it fulfills the identified requirements for a learning path description. Further refinement will be needed, though. Through its integration with the TENCompetence pilot in 2008, the evidence of the learning path specification to facilitate automated generation of positioning and navigation support will be evaluated. In addition, the specification will be refined, based on the requirements identified in our research on CDP authoring tools.

Three prototypical tools for curriculum planning have been developed, based on background research on curriculum planning, as described in chapter 3. The first prototypic CDP composer is mainly a whiteboard design, which sketches user interface requirements for future tools. This tool is developed, based on the domain of the TENCompetence Digital Cinema Pilot. The second tool, a running prototype for graphical curriculum planning, is less advanced as far as user interface issues are concerned, but provides a running environment for testing purposes. The functionality includes graphical overviews of the class ontology, relation graphs and instance graphs. Further, a query interface provides graphical feedback on specific relations between units of learning. Functionality for curriculum planning and scheduling is available. As a third prototype, we extended an algorithmic curriculum planning tool and evaluated this in the domain of the Computer Science Curriculum of the University of Hannover. Future work will concentrate of the integration of the successful features of the prototypes, as well as on answering questions on limitations in granularity of visualization and support for exploratory search by authors and students alike. It has become apparent that visualization approaches are rarely used in the field of e-learning, let alone in the field of computer-supported lifelong learning, which means that this line of research is particularly challenging and unprecedented. An important next step will be the design, evaluation and integration of suitable metaphors for curriculum authoring and planning.

Three implementations of the envisaged adaptive functionality have been presented in chapter 5. A *positioning service*, based on Latent Semantic Analysis and Reduced Rank Vector Models, has been developed and is currently evaluated in a user study. Further research will focus on the combination of content-driven, metadata-driven and ontology-based approaches. The *navigation service* provides a hybrid recommender system for next-best steps while following a curriculum. It has been successfully evaluated in a user study and further studies are planned. APIs of these two services have been developed for integration in the TENCompetence client. In order to provide recommendations in situations in which not sufficient peer students are available, an alternative navigation service, based on *preferences* has been developed for providing an optimal subset – the s*kyline* – of all possible learning activities. The innovative aspect of the skylining procedure is that it identifies objects that are consequently worse than other candidates; the remaining best objects – which perform better on at least one of the provided criteria – provide a limited set of relevant learning activities, without forcing the learner to specify a preference order for the criteria. This skylining service is expected to improve the results of both the positioning and navigation services.

In conclusion, during the first project cycle of TENCompetence, work package 7 has identified the current state-of-the-art in the field of Curriculum Development Programmes. Based on the results presented in this deliverable, we have separated three individual yet related tracks of research to be followed. The first track is to build the central model for the learning path description (LPD). We focus here on the core, which is the description of curricula on themselves. For this purpose, we adopt an approach that is heavily based on IMS Learning Design. Our contribution will be to relate the LPD to other relevant models, such as the underlying domain (competence) model and the learner model. Further, the LPD will be checked against the needs identified by the design of authoring tools (track 2) and the goals it needs to serve, as identified by the learner-adaptive technology (track 3). The second track, the design of authoring tools for curriculum development programmes, extends the current practice of curriculum editors by providing enhanced visualizations that take the fundamentals of GUI design and information visualization into account. The next challenge will be the design, implementation and evaluation of suitable metaphors. The third track, learner-adaptive technology, concentrates on positioning and navigation services. We explore the feasibility and effectiveness of various techniques, including latent semantic analysis, collaborative filtering and skylining. User studies will be carried out to further improve these techniques and to provide pointers to integrate the approaches into one innovative concept.

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